Series II, Volume 6 June 22, 1961 Number 4

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1961 SUMMER MEETING

WITH LA SOCIEDAD MEXICANA DE FISICA

MEXICO CITY

June 22–24, 1961

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June 22, 1961 Series II, Vol. 6, No. 4

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1961 Summer Meeting at Mexico City, June 22–24, 1961, being a Joint Meeting with La Sociedad Mexicana de Física

WE are going to Mexico again! To those who attended our conventions of 1950 and 1955 in Mexico City, and to those who have visited Mexico for other purposes, this news is bringing happy memories and eager anticipations. Those who have never been in Mexico have a wondrous new experience before them. We shall not revisit (unless as tourists) the scenes of our 1950 meeting, but on Thursday we shall return to those of our 1955 meeting in the Ciudad Universitaria, which did not yet exist in 1950. On Friday and on Saturday the scenes will be new to us all, for we shall convene in the Centro Médico. As in 1955 this is a joint meeting with the Sociedad Mexicana de Física, to many of whose officials (listed, so far as their names are known to us, on page 407) we shall be greatly in debt for making the necessary arrangements.

Entry into Mexico. Citizens of the U.S.A. or of Canada must obtain (for $3.00) a **tourist card** from a Mexican Consulate. Proof of citizenship must be shown; examples of such proofs are birth certificates, naturalization certificate, voting certificate, passport, or Army or Navy discharger certificate. (For naturalized citizens, either the naturalization certificate or the U.S.A. passport must be shown). A certificate of vaccination against smallpox also must be provided. Be sure to bring your proofs and your vaccination certificate with you into Mexico and to keep them available throughout your journey.

Mexican Consulates are to be found in many major cities of the U.S.A., presumably also in major cities of Canada, and in border cities including Laredo, Eagle Pass, El Paso, Nogales, and Calexico. For those who cannot readily reach any of these, the Mexican Government Tourist Bureau at 630 Fifth Avenue, New York 20, New York, kindly offers to handle the transaction by mail. You must write to it for a form ("application for a tourist card to visit Mexico"), fill out the form, and send it back with photostats of your proofs (it is, however, unlawful to photograph a naturalization certificate!) and with a check made out to "Mexican Government Tourist Department" for the appropriate amount. Apparently separate forms are required for husband, for wife, and for any child of fifteen or over. Opposite the question "object of trip" write either "pleasure" or "convention," and opposite the question "final destination" write the name of the farthest point to be visited in Mexico. Do all this right away. Your tourist card may be used at any time within three months of its issuance, and once you are across the Mexican border it remains valid for six months.

Citizens of other countries than the U.S.A. and Canada must go to a Mexican Consulate to get Mexican visas on their passports and must bring the passports with them to Mexico.

Access to Mexico. There is a train from San Antonio, Texas, to Mexico City; it leaves the former at 12:40 p.m., and is scheduled to arrive at the latter at 8:10 p.m. on the following day; the scenery along the Mexican part of the route is magnificent. San Antonio is reached by the Southern Pacific from New Orleans or from Los Angeles, and by the Missouri Pacific from St. Louis; there are, at least at this writing, through Pullmans from New York over the Pennsylvania and the Missouri Pacific. There are also trains to Mexico City from Ciudad Juarez (across the border from El Paso) and from Mexicali (across the border from Calexico). Information about driving to Mexico should be sought from the Mexican Government Tourist Bureau or from your automobile association, and information about flying from the airlines or your travel agent.

Hotels. Repeating what was said in the two latest previous issues of this Bulletin: rooms have been booked for our members in hotels of three cate-

gories. The *de luxe* category includes the Hotel del Prado, Alffer, Bamer, Continental Hilton: its price range, in U.S.A. dollars, is $16 to $13.60 double, $14 to $12 single. Of the "superior first-class" category are the Cristobal Colon, San Francisco, Diplomatico ($10 to $8 double, $8 to $7.20 single). Of the "first-class" category are the Prince, Regis, Metropol ($8.50 to $6.80 double, $7.60 to $4.80 single). These prices do not cover any meals.

All hotel reservations are to be made by writing to Pancho Lona Tours, Balderas 32 (primer piso), Mexico 1, D.F., Mexico. Use 7-cent airmail stamp. With your letter of reservation send a deposit sufficient to cover the first night; it will be refunded if you give 72 hours' notice of cancellation. We were informed that all reservations had to be made before June 10. We hope, therefore, that all who are coming to our convention took appropriate action when they saw the announcement in the previous issues of this Bulletin. If you did not, try anyhow.

A piece of good news hitherto unpublished is that Pancho Lona Tours will send a representative to meet you at the railway station, bus terminal, or airport, provided you notify them in advance of the train, bus, or plane by which you expect to arrive.

Access to the meeting places. Ciudad Universitaria and Centro Médico are both in the outskirts of Mexico City, several miles from the hotels. You can go easily by taxi from the hotels to either; on Thursday you say "Facultad de Ciencias" to the driver, and "Centro Médico" on Friday and Saturday. Allow forty-five minutes to go from the hotels to the former and twenty-five to go to the latter. All this is simple enough; but picking up a taxi for the return journey is quite another matter, and therefore we advise our members to avail themselves of the buses which our Mexican hosts will provide. These will start from the Hotel del Prado at nine, will pause at the Continental Hilton a few minutes later to pick up passengers, and will pause once more at the Diplomatico a few minutes later still. The other official hotels are within a few minutes' walking distance of the Hotel del Prado. Coming back, the buses will start at 17:30 (note that we are using the admirable twenty-four-hour clock customary in Mexico and on the Continent of Europe). The round-trip costs $2.30 U.S.A.—note that we say U.S.A. dollars, because the symbol $ is used in Mexico for the peso—and tickets may be bought at the registration desk. Once you are either at the Facultad de Ciencias or at the Centro Médico, signs set up by our hosts will guide you.

Registration. On the evening before the meeting begins (Wednesday evening, June 21) there will be a registration desk at the Hotel del Prado, open from 17 to 21. Register then and there if you possibly can. The next chance will be at the Torre de las Ciencias in the Ciudad Universitaria, from 9 to 13 and from 14:30 to 18 on Thursday. As soon as you get to the desk, buy your **luncheon tickets for all days** of the meeting ($1.75 each day, tips included), your banquet ticket ($6, tips included), and your bus tickets. Examine the nearby blackboards for notice of new arrangements. If the desk at the Hotel del Prado is not briefly open on Thursday morning for the sale of bus tickets, some other arrangement will be made; ask at the hotel desk. There will be no registration fee.

Bring your copy of the Bulletin with you; we may not be able to get a sufficiency of copies to the meeting on time for distribution.

Blunt advice. Mexico is a very foreign land, differing from the U.S.A. in altitude, summer weather, food, drink, the rules of propriety in attire, and many other things. Therefore take what follows in good part.

The altitude of Mexico City is 7200 feet, and the passes over the mountains that surround it rise to 10 000 feet. Therefore do not be surprised if you get out of breath easily or find stairways hard to climb at your usual pace. The summer temperature ranges from around 80° in the early afternoon to around 60° at night, and rain falls in the late afternoon and/or early evening of practically every day; be prepared. What has just been said is more or less true for the whole "meseta" or high plateau that extends for many miles in all directions from Mexico City; but if you descend into the coastal lowlands or go south of Oaxaca, expect hot, sultry weather.

Mexicans care more for decorum in attire than do some denizens of the U.S.A. Beachwear is all right on the beaches and around the swimming pools of hotels that have such, and play clothes on the playing fields, but not elsewhere. Ladies do not wear pants or slacks, and nobody wears shorts, on the Paseo de la Reforma or anywhere else in town. Clothing suitable for a good restaurant in New York is suitable anywhere.

There may be people who have such a strong natural immunity that they can eat and drink in Mexico as freely as they do at home, but it is decidedly unwise to assume that you are one of them unless you know. The policy of prudence is to avoid everything uncooked. Do not drink water, except bottled water (and if the waiter brings the bottle open to your table, send it back and demand a bottle to be opened in your presence). Beware of milk, cream, or ice cream. Avoid salads; avoid uncooked fruits and vegetables, except such as you buy in the market, wash, and cut or peel with a

disinfected knife. Remember that ice is water and that alcohol mixed with water in potable proportions is not a reliable germicide. If this sounds like austere living, consider that a sojourn in Mexico is worth a little austerity. You can enjoy tapwater and iced drinks and salads after you get home again.

The conventional dinner hour in Mexico is very late by Northern standards, and until you readjust yourself you may do well to get a snack around 18.

Very many Mexicans have learned English with varying degrees of excellence including the highest, and therefore it is possible for a visitor from an English-speaking country to enjoy his visit without knowing a word of Spanish; many do. Nevertheless it is a nice gesture to try to learn at least a little of the language of the country, and any effort of the kind that you may make will be amply repaid in enhanced enjoyment of your sojourn, not to speak of other advantages. Spanish is a beautiful language, a rich language, and a world language.

The meeting itself. After so lengthy a preamble to this preamble, we yield to the temptation of asking our members to acquaint themselves with the programme by reading it in the pages that follow. Our Divisions of Electron Physics, of Fluid Dynamics, and of Plasma Physics have contributed nobly to the group of invited papers. Special Committees consisting each of an appointee of La Sociedad Mexicana de Física and an appointee of The American Physical Society have set up programmes of invited papers in cosmic-ray physics, experimental nuclear physics, theoretical nuclear physics, and solid-state physics. A few other invited papers have been bespoken by the Secretary, but these are only a few because of the unexpectedly immense size of the meeting. The "population explosion" which befalls one after another of our conventions in quick succession has now arrived at our Mexican sequence. (It is interesting to observe that the Presidential career of Frederick Seitz, which began as lately as February 4 of this year, already has included the largest Pacific-Coast meeting in our history, the largest Spring meeting and thereby the largest altogether in our history, and now the largest Mexico meeting in our history). In 1950 and in 1955 we deplored the smallness of our meeting in Mexico; now we are awed by its greatness.

The banquet of the two Societies will be held on Friday evening at 20:30 in the Hotel del Prado. The after-dinner speakers will be announced at the registration desk if not in these pages. We hear that even the grandest of Mexican hotels, though in no wise inferior in grandeur to those of the U.S.A., do not generally have ballrooms or banqueting halls as big as those available in the North. Therefore make haste to get your tickets at the registration desk; otherwise you may find yourself left out. The price will be six dollars (U.S.A.) tips included.

The **Council of The American Physical Society** will convene somewhere and sometime during the meeting; notice will be sent to its members.

Post-deadline ten-minute papers, pertaining to very recent achievements of very special significance, will be considered for admission to the programme if abstracts are received not later than Friday, June 16, in Mexico City: address them to Professor Marcos Moshinsky, Apartado Postal 31364, Mexico 20, D.F. The titles of such as are accepted will appear on a blackboard near the registration desk. They may be assigned to Session XA, or distributed among other sessions according to their subjects, or some may be handled one way and some the other.

Preliminary announcements of the Thanksgiving meeting and the Winter Meeting on the West Coast will be found on page 403.

Announcements of topical conferences will be found on pages 403, 404, and 405. Among these is included the announcement of a Cosmic-Ray Symposium to be held in or near Mexico City soon after ours is over. This is not a Topical Conference in the special sense that these words carry in our Society, but its importance and its locality justify its inclusion.

Instructions for the preparation of abstracts are printed on page 406 of this Bulletin. Read and heed them! People are again getting careless about submitting abstracts broken into paragraphs. Notice is hereby given that henceforth all such will be rejected.

Errata pertaining to abstracts in this issue will be published in a later issue of this Bulletin if received not later than Monday, June 26, by Miss Ruth F. Bryans, American Institute of Physics, 335 East 45 Street, New York 17, New York. Do not send in the abstract defaced with erasures and corrections. Write out your corrections in the form "Instead of . . . read . . . ." Add nothing.

Repetition: **bring your copy of this Bulletin with you to Mexico,** for we may not be able to provide on time the usual supply at the registration desk. **Si quiere leer este programa y los resúmenes en español,** escriba al Señor Doctor Marcos Moshinsky, Apartado Postal 31364, Mexico 20, D.F., Mexico.

KARL K. DARROW, *Secretary*
American Physical Society
New York 27, New York

EPITOME OF THE 1961 MEXICO MEETING

(Personal names are those of invited speakers. DEP, DFD, and DPP stand for the Divisions of Electron Physics, Fluid Dynamics, and Plasma Physics.)

CIUDAD UNIVERSITARIA

THURSDAY AT 10:00

Inaugural Session Faculty of Sciences

THURSDAY MORNING AT HOURS STATED IN THE MAIN TEXT

A. Singer, Lockwood, Chasson. Engineering School.
B. Bell; radioactive nuclei. Chemistry School.
BA. Optical and x-ray physics. First Floor, Tower of Sciences.
C. Cryogenics; general solid-state physics. Eighth Floor, Tower of Sciences.
CA. Darrow, Townes. Faculty of Sciences.
D. Chemical physics; fluid dynamics I. "B" in Chemistry School.

THURSDAY AT 14:30

E. Vallarta, McDiarmid, Green, Bailey, Earl. Engineering School.
F. Nuclear Reactions; proton-proton scattering. Eighth Floor, Tower of Sciences.
FA. DEP: Thermionic energy-converter: Nottingham, Rasor, Hernqvist, Agnew, Webster. Faculty of Sciences.
G. Semiconductors. Chemistry School.
H. Theoretical Physics I. First Floor, Tower of Sciences.
HA. Fluid Dynamics II. "B" in Chemistry School.

CENTRO MEDICO

FRIDAY AT 10:00

J. DFD: Emmons, Schaaf, Kolb, Morawetz. Auditorium 7, "B" Building.
K. Strange particles and mesons; Lindenbaum. Auditorium 3.
KA. Metals; magnetism. Auditorium 4.
L. Medina, Moshinsky, Eden, Feynman. Auditorium 2.
M. Apparatus of nuclear physics. Auditorium 6.
MA. Electron Physics I. Auditorium 5.

FRIDAY AT 14:30

N. Electron Physics II. Auditorium 5.
P. Korff; cosmic rays and space. Auditorium 3.
PA. Alba, Phillips, Davis, Havens. Auditorium 2.
Q. Magnetic resonance; masers. Auditorium 6.
QA. DPP: Bernstein, Tuck, Drummond, Griem. Auditorium 7.
R. Theoretical Physics III. Auditorium 4.

HOTEL DEL PRADO

FRIDAY AT 20:30

Banquet of the two Societies. Hotel del Prado.

CENTRO MEDICO

SATURDAY AT 10:00

S. Neutron Physics I. Auditorium 6.
T. Plasma I. Auditorium 3.
U. Theoretical physics III. Auditorium 4.
UA. Pound, Urey, Dryden. Auditorium 7.
V. DEP: Particle impact phenomena: Mueller, Wehner, Vineyard. Auditorium 5.
VA. Fernandez, Hanna, Hebel, Prieto, Yarnell. Auditorium 2.

SATURDAY AT 14:30

W. Feher, Hensel, Corbett, Sugano. Auditorium 7.
WA. DEP: Atomic Collisions: Spruch, Bederson. Auditorium 2.
X. Neutron Physics II; fission. Auditorium 6.
XA. Post-deadline Papers, if any. Auditorium 5.
Y. Theoretical Physics IV. Auditorium 4.
Z. Plasma II. Auditorium 3.

PROGRAMME

THURSDAY AT 10:00

Auditorium of the Faculty of Sciences

Inaugural Session

Greetings of the University of Mexico. DR. IGNACIO CHAVEZ, *Rector de la Universidad Nacional Autónoma de Mexico.*

Greetings of the Sociedad Mexicana de Física. DR. FERNANDO ALBA ANDRADE, *Presidente en funciones de la Sociedad Mexicana de Física.*

Response for the American Physical Society. DR. FREDERICK SEITZ, *President of The American Physical Society.*

THURSDAY AT 11:00

Auditorium of the Engineering School

(MANUEL SANDOVAL VALLARTA presiding)

Invited Papers in Cosmic-Ray Physics, I

A1. Protons Trapped in the Geomagnetic Field. S. F. SINGER, *University of Maryland.* (30 min.)

A2. Forbush Decreases in the Cosmic Radiation. J. A. LOCKWOOD, *University of New Hampshire.* (30 min.)

A3. Fine Structure of Forbush Decreases of Cosmic Rays. R. L. CHASSON, *University of Nebraska.* (30 min.)

THURSDAY AT 11:30

Auditorium of the Chemistry School

(A. MORENO Y MORENO presiding)

Invited Paper

B1. Progress in Electronic Measurement of Short Nuclear Lifetimes. R. T. BELL, *McGill University, Montreal.* (30 min.)

Radioactive Nuclei

B2. Shape of the O+ to O+ Ga^{66} Positron Spectrum.* L. M. LANGER, D. C. CAMP, AND D. R. SMITH, *Indiana University.*—A detailed magnetic spectrometer study was made of the shape of the positron spectrum of the 4.17-Mev O^+ to O^+ transition in the decay of Ga^{66}. From the end point down to 1.80 Mev, the shape factor is found to be statistical. No shape factor of the form $1+b/W$ with $b>0.1$ can be made to fit the data. This is to be compared with other measurements,[1] under essentially identical conditions, which have either required or could not deny a value of $b \geqq 0.3$. All previous measurements were on pure Gamow-Teller or mixtures of Gamow-Teller and Fermi transitions. The Ga^{66} decay is presumably a pure Fermi transition involving only the vector interaction. Pearson's explanation of the small deviations[2] that have been observed, in terms of an induced pseudoscalar interaction, would be consistent, of course, with the fact that such a deviation is not observed in the case of Ga^{66}.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1] O. E. Johnson, R. G. Johnson, and L. M. Langer, Phys. Rev. 112, 2604 (1958); J. H. Hamilton, L. M. Langer and W. G. Smith, *ibid.*, p. 2010; J. H. Hamilton, L. M. Langer and W. G. Smith, *ibid.*, 119, 772 (1960).

[2] J. M. Pearson, (private communication submitted to Phys. Rev.)

B3. Isospin Conservation in the β Decay of Sc^{44}.* S. D. BLOOM, L. G. MANN, AND R. J. NAGLE, *Lawrence Radiation Laboratory, Livermore.*—The one published measurement[1] of the β-γ circular polarization for Sc^{44} $[2^+(\beta^+)2^+(\gamma)(0^+)]$ indicates a large-scale breakdown of isospin conservation, since the essentially zero polarization value reported[1] ($A=-0.02 \pm 0.04$) corresponds to a matrix element for the Fermi contribution to the β decay which is $\sim -18\%$ of the Gamow-Teller part. The result at this laboratory[2] for Sc^{46} indicates that isospin is, on the contrary, conserved at least within the minimal experimental error achievable with present techniques (Fermi contribution $<\sim 2\%$). Consequently, it was felt important to re-examine the case of Sc^{44}. This was done using the same technique of rapid alternation reported previously,[2] with some improvements due to better shielding and more accurate calculations of the various correction factors. The result to date is that the polarization is definitely nonzero: $A=-0.125\pm0.025$. This corresponds to a Fermi/Gamow-Teller ratio ($C_V M_V / C_A M_A$) of -0.05 ± 0.03. The smallness of this result is in consonance with our earlier Sc^{46} result[2] and

hence with the validity of the isospin quantum number in this atomic weight region.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] F. Boehm and A. H. Wapstra, Phys. Rev. 109, 456 (1958).
[2] S. D. Bloom, L. G. Mann, and J. A. Miskel, Phys. Rev. Letters 5, 326 (1960).

B4. Beta-Gamma Directional Correlation in the Decays of Ga^{72} and La^{140}.* J. E. ALBERGHINI AND R. M. STEFFEN, *Purdue University.*—The directional correlation between the nonunique first-forbidden 3.15-Mev β-ray group of Ga^{72} and the 0.840-Mev γ ray in Ge^{72} has been measured as a function of the β energy. The equipment used is the same as described before.[1] The anisotropy factor $A_2(W)$ in the directional correlation function $w(\theta)=1+A_2(W)P_2(\cos\theta)$ ranges from -0.27 ± 0.02 to -0.35 ± 0.02 in the β-energy range from $W=5.9$ to $W=7.0$. The directional correlation and the shape factor[2] data can be reasonably well fitted with the matrix element parameters (in Kotani's notation[3]): $z=1$, $Y=+1.25$, $x=-0.15$, and $u=-0.05$. This is one of a few sets which give a good fit of the data. The anisotropy factor $A_2(W)$ of the β-γ directional correlation involving the 2.2-Mev β group of La^{140} ranges from $+0.10\pm0.02$ to $+0.13\pm0.02$. The energy dependence of $A_2(W)$ excludes the possibility of a unique first-forbidden transition. The directional correlation and shape data are well fitted by the set $z=1$, $Y=-1.25$, $x=-0.1$, $u=+0.2$, among a few others. No fit is possible by the "modified B_{ij} approximation."[3]

* Supported by the U. S. Atomic Energy Commission.
[1] R. M. Steffen, Phys. Rev. 118, 763 (1960).
[2] L. M. Langer and D. R. Smith, Phys. Rev. 119, 1308 (1960).
[3] T. Kotani, Phys. Rev. 114, 795 (1959).

B5. Level Structure of Pm^{147}. JOHN D. ROGERS, *California Institute of Technology, Pasadena, California.*—Studies were made of the angular distribution of six γ rays in Pm^{147} from the decay of Nd^{147}. The Nd^{147} nuclei were included in Nd-ethylsulfate crystals and aligned at low temperature. All distributions observed were of the form $\omega(\theta)=1+A_2P_2(\cos\theta)$. The resultant anisotropies, when combined with results of angular correlation measurements,[1] allow conclusive assignments of the spins of five levels in Pm^{147}. These are 0, 7/2+; 91.08, 5/2+; 410.6, 3/2+; 531.0, 5/2+; 685.9, 5/2+. The assignment of the 489.4 level is uncertain. These spin assignments are in agreement with those tentatively suggested by Ewan *et al.*[2] on the basis of conversion electron measurements. Westenbarger and Shirley[3] recently have obtained similar results on the basis of nuclear alignment studies.

[1] E. Bodenstedt, H. J. Körner, F. Frisius, D. Hovenstadt, and E. Gerdau, Z. Physik 160, 33 (1960).
[2] G. T. Ewan, R. L. Graham, and J. S. Geiger, Bull. Am. Phys. Soc. 6, 238 (1961).
[3] G. A. Westenbarger and D. A. Shirley (to be published).

THURSDAY AT 11:00

First-Floor Auditorium, Tower of Sciences

(T. A. BRODY presiding)

Optical and X-Ray Physics

BA1. Calculation of Equivalent Width of a Single Line.* HENRY MARGENAU, *Yale University,* AND J. SOKOLOFF, *Lockheed Missiles and Space Division.*—The "equivalent width" of a single line[1]

$$W=\int_{\Delta\nu}[1-\exp(-uSb)]d\nu,$$

where u is the mass of the absorbing gas per unit area, S is the total intensity of the line, and b is the line shape factor normalized to unity, has been calculated allowing the half-width to vary linearly with the density of the gas and allowing the line center to shift linearly with density. The line was assumed to have the Lorentz shape. Two types of absorbing gases were treated: a gas in which the density varied linearly with distance and a gas in which the variation is exponential. The optical depths and equivalent widths for the linearly varying gas and the exponentially varying gas are compared to the results obtained by the method of Ladenburg and Reiche[2] for a constant density gas.

* Supported by General Research funds of Lockheed Missiles and Space Division.
[1] Gilbert N. Plass, J. Opt. Soc. Am. 48, 690 (1958).
[2] R. Ladenburg and F. Reiche, Ann. Physik 42, 181 (1913).

BA2. Infrared Absorption of Carbon Monoxide at High Temperature. WILLIAM O. DAVIES, *Armour Research Foundation.*—The absorption of carbon monoxide argon mixtures was determined at wavelengths of 4.60μ, 4.67μ, and 4.72μ over a temperature range from 1160° to 2300°K. The high temperatures were obtained by passing a shock wave through the test gas. Temperature and pressure of the test gas were determined from measurements of initial concentrations and shock wave velocities, using known thermodynamic properties of gas mixtures. The total pressures of the test gas varied from 1.7 atm to 3.7 atm, which correspond to carbon monoxide optical densities of 5 atm-cm to 11 atm-cm. Absorption was observed as a diminution of source beam intensity monitored with a rapid response infrared detector. Average absorption coefficients over the slit width (22 cm^{-1}) and total pressure are obtained by use of Beer's law. Because of incomplete pressure broadening at these pressures, a decrease in transmission is observed as total pressure is increased; the Beer's law plots are made linear by an empirical correction proportional to $P^{\frac{1}{2}}$. A reduction in observed absorption coefficient with temperature is compared to the theoretical value obtained by averaging over slit width and accounting for the variation of apparent integrated absorption with temperature and pressure.

BA3. Applications of the SPO (Split p-Orbital) Method to Alternate Molecules. M. J. S. DEWAR AND N. L. H. DE SABELLI,* *University of Chicago* (introduced by J. W. Stout).—The SPO method[1] considers the probability of finding both electrons in the same p-lobe of a C atom as zero, to introduce in a nonempirical way the effects of vertical electron correlation in the LCAO treatment of unsaturated molecules. The results of a study of several alternant molecules with this method will be described. The transition energies, calculated with or without configuration interaction, are found to agree closely with experiment. The contribution of excited configurations to the ground state total wave function is less important in the SPO model than in the conventional LCAO ones, as has been found for several semiempirical treatments.

* External fellow of the Consejo Nacional de Investigaciones de la Republica Argentina.
[1] M. J. S. Dewar and N. L. Hojvat, J. Chem. Phys. 34, 1232 (1961).

BA4. Mathematical Representation of Molecular Spectra.* V. R. STULL, P. J. WYATT, AND G. N. PLASS, *Aeronutronic.*—Despite the advent of ultra-high-speed electronic data processing systems, the exact calculation of the emission and absorption spectra arising from molecular gases has long been considered impractical. In recent years various approximation methods have been developed whose agreement with observed spectra is sometimes rather good. Important modifications necessary to increase the accuracy of the models over a wide range of path lengths and pressures will be discussed. Specific emphasis will be directed toward an improved (and necessarily more complicated) statistical model as well as a comparison of an "exact" analysis of a particular spectral band with a modified Elsasser description. Application of these methods to the atmospheric transmission problem will be described.

* Supported by the Geophysics Research Directorate, U. S. Air Force Research Division, Bedford, Massachusetts.

BA5. Index of Refraction of CdS at Various Pressures and Temperatures. D. W. LANGER, *Wright-Patterson Air Force Base* (introduced by Lee Devol).—The index of refraction of CdS was measured by the interference method in the wavelength region between the absorption edge and 6500 A both modes of polarization. The CdS platelets (4 to 39 μ thick) were kept at temperatures of 77°, 188°, 295°, and 358°K and simultaneously under hydrostatic pressure. The pressure range was varied up to 10 kilobars; measurements at atmospheric pressure also were carried out at intermittent temperatures and as low as 4°K. The results can be qualitatively interpreted according to the classical dispersion theory by a change of the oscillator frequency and the damping factor due to a temperature change, and a change of only the oscillator frequency due to the pressure change. The temperature coefficients were found to be independent of the applied pressure, and pressure coefficients independent of the temperature.

BA6. Measurements of Oxygen Opacity.* D. E. BUTTREY AND K. K. CHAN, *Lockheed Missiles and Space Division* (introduced by M. Walt).—Measurements of the absolute spectral radiant intensities have been made of the continuum radiation from doubly shocked oxygen for equilibrium conditions of 18 600°K and one-fifth normal density. Emissivities inferred from the data have been compared with emissivities predicted by the photoelectric cross sections for neutral oxygen of Boldt[1] and Meyerott *et al.*[2] and by the O^- photodetachment cross sections of Branscomb *et al.*[3] Under these thermodynamic conditions the concentrations of O and O^- are not sensitive to the temperature in the gas. The O^+ concentration is one-fourth that of neutral atomic oxygen, and hence the O^+ photoelectric effect is expected to make a contribution to the observed radiation. One percent impurity of hydrogen was introduced, and the time-resolved Stark-broadened Balmer lines were used to determine the ion density in the gas using the theory of Griem-Kolb-Shen to interpret the line profiles.

* Supported in part by the U. S. Air Force Special Weapons Center.
[1] Boldt, Z. Physik **154**, 330 (1959).
[2] Meyerott, Sokoloff, and Nicholls, Geophysics Research Papers (September, 1959).
[3] L. M. Branscomb, D. S. Burch, S. J. Smith, and S. Geltman, Phys. Rev. **98**, 504 (1958).
[4] H. R. Griem, A. C. Kolb, and K. Y. Shen, Phys. Rev. **116**, 4 (1959).

BA7. Isotope Shift in the Spectrum of Atomic Silicon.* JOHN R. HOLMES AND MARTIN E. HOOVER, *University of Southern California.*—The isotope shift of Si^{30} relative to Si^{28} has been measured in eleven atomic spectral lines, using a Fabry-Perot interferometer. The spectra of two samples of elemental silicon enriched to 72.56% in Si^{30} and 99.4% in Si^{28}, respectively, were excited in two hollow cathode discharge tubes cooled in liquid nitrogen. Both tubes were attached to one end of a Pyrex ground joint which was mounted in a vertical position to permit a change from one source to the other by rotating the tube assembly. Neon was used at a pressure of approximately 0.40 mm Hg to carry the discharge. The magnitudes of the observed shifts vary from $\Delta\nu \sim 0.011 \pm 0.001$ cm^{-1} for the $(3p^2\ ^3P^0 - 4s\ ^3P^0)$ transition to $\Delta\nu \sim 0.115 \pm 0.002$ cm^{-1} for the $(3p^2\ ^3P^0 - 3d\ ^3D^0)$ transition. Experimental results indicate that the specific mass shift of the $3d\ ^1D_2^0$ level relative to the $3d\ ^1F_3^0$ level is about seven times as large as the specific shift in the λ-2435 $(3p^2\ ^1D_2^0 - 3d\ ^1D_2^0)$ transition.

* Partially supported by the Office of Naval Research.

BA8. Zeeman Effect of the Transition Pu^{+++} $^6H_{\frac{1}{2}} \rightarrow J = 11/2$ in Hexagonal Single Crystals.* H. LÄMMERMANN† AND J. G. CONWAY, *Lawrence Radiation Laboratory, Berkeley.*—Polarized optical absorption and fluorescence spectra and Zeeman effect of 0.1–2% Pu^{+++} in lanthanum ethylsulfate and lanthanum trichloride single crystals have been investigated at 4.2°K, 20°K, and 77°K. As in the corresponding rare earth Sm^{+++}, well-separated groups of lines are observed, each of which represents an electrical dipole transition between the crystal field components of two levels of the configuration $5f^5$. The over-all splitting of the levels and the linewidths are about the same for both elements. Thus, for the plutonium ion, the crystal field exhibits only a small perturbation. Especially one group corresponding to a transition between the ground level $^6H_{5/2}$ and probably $^6F_{11/2}$ will be discussed in detail. Crystal field quantum numbers, matrix elements, eigenfunctions, and g factors are determined experimentally.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
† Supported by the German Ministry for Atomic Energy and Scientific Research.

BA9. X-Ray Fluorescence Chemical Analysis by Means of a Spectrodiffractometer. OCTAVIO CANO-CORONA, *Institute of Physics, National University of Mexico.*—As is well known, x-ray fluorescent intensity of an element in a sample depends on the concentration of the element as well as on the absorption characteristics of the sample itself. Therefore, there is no linear connection between the concentration and the fluorescent intensity. Nevertheless, we obtain an approximate linear relationship between the concentration and the product μI_r, where μ represents the product of a constant by the mass absorption coefficient of the sample, for the particular wavelength employed in the analysis, and I_r represents the relative fluorescent intensity of the sample with respect to the fluorescent intensity of a pure compound of the element in consideration, such as an oxide. The value of μ is obtained also by means of the spectrodiffractometer. This result has been proved for uranium, thorium, and tin. Analysis of uranium samples artificially prepared checked within 5% with respect to the amount of uranium in the samples.

BA10. An Unsymmetrical Effect with Bremsstrahlung. ARNOLD KELLER, *Universidad Tecnica Federico Santa Maria, Valparaiso, Chile.*—A beam of bremsstrahlung was allowed to strike the inner surface of the Cu cylinder of a GM counter tube with a fixed angle of incidence of 80°, the electrons in the X tube moving in the plane of incidence. The counting rate showed a difference of $(0.8 \pm 0.3)\%$ between the two positions. If this asymmetry is interpreted as due to the photoelectric effect, it means that the probability for an electron to be ejected in the same direction as the electrons in the X tube move is a little smaller than in the opposite direction. It means that the photoelectric effect depends not only on the Fourier amplitudes of the electromagnetic irradiation, but also a little on their phase relations. The possibility of measuring crystal phases by the unsymmetrical effect is outlined.

THURSDAY AT 11:15

Eighth-Floor Auditorium, Tower of Sciences

(JOHN YARNELL presiding)

Cryogenics; General Solid-State Physics

C1. Recoil-Free Gamma Ray Emission in a Ferromagnetic Superconductor.* P. P. CRAIG, D. E. NAGLE, D. R. F. COCHRAN, AND R. D. TAYLOR, *Los Alamos Scientific Laboratory.*—The ferromagnetic superconductor[1] $Y_{0.925}Gd_{0.075}Os_2$ has a Curie point at $T_c=3.2$°K and becomes superconducting at $T_s=2.4$°K. We have begun a study of the Mössbauer effect in this material in an effort to determine whether internal magnetic fields exist when the substance is in the superconducting state.[2] A resonant source was prepared by diffusing into a ground and polished surface of the ferromagnetic superconductor about 2 mC of Co^{57}. This source was mounted inside a helium cryostat equipped with Be and Al windows. With an absorber of 1.7 mg/cm² of Fe^{57} and the source at a temperature of 4°K, the resonance linewidth was 0.76 mm/sec. Upon cooling the source to 2.0°K the resonance amplitude decreased by 0.1%±0.1%. Shifts in the line position and line broadening were both less than 0.01 mm/sec. The Debye temperature of the material in the superconducting state therefore decreases by less than 10°K. The change is of interest in connection with recent measurements on the lattice specific heat of superconductors.[3]

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] H. Suhl, B. T. Matthias, and E. Corenzwit, J. Phys. Chem. Solids **11**, 346 (1959).
[2] P. P. Craig, D. E. Nagle, and R. D. Reiswig, J. Phys. Chem. Solids **17**, 168 (1960).
[3] C. A. Bryant and P. A. Keesom, Phys. Rev. (to be published).

C2. High-Field Studies of Nb_3Sn Superconductivity. C. E. ROOS, *Vanderbilt University*, AND J. O. BETTERTON, R. W. BOOM, G. J. KNEIP, AND R. WORSHAM, *Oak Ridge National Laboratory.*—The critical current has been measured as a function of field for Nb-clad Nb_3Sn superconductors. The Vanderbilt magnet is compensated and has a 1.2-msec period so that the field is constant to 2% in both the experimental volumn (30 cc) and during the period when the measurements were obtained. A current pulse of variable duration is fed to the sample near peak field. The sample was mounted as noninductively as possible (5×10^{-9} h). The system was calibrated and the resistive sensitivity was 0.05 mohm. The voltage response for a superconductor is inductive, being a minimum at the current maximum. The Nb clad becomes normal at very much lower current densities and field strengths than required to quench superconductivity in the Nb_3Sn core. Whenever the clad was driven normal by the current (zero-field runs) a sharp change in the inductive response of the sample was noted. This can be fully explained by the shift of current from the normal clad into the superconducting core. When the core is driven normal there is a sharp change in the magnitude and phase of the voltage response of the sample. The transition time for the core to go fully normal appears to be 4 μsec. The critical field at 4.2°K is 125 kgauss.

C3. Superconductivity of Some Intermetallic Compounds. R. D. BLAUGHER, *Martin Company*, AND J. K. HULM AND A. TAYLOR, *Westinghouse Research Laboratories.*—The W-Os, Re-W, Re-Mo, Re-Hf, and Mo-Hf binary systems were investigated for superconductivity down to 1°K. Four new superconducting regions—alpha manganese, ε-hexagonal, β-hafnium and θ-osmium—were found in these five systems. The sigma region in W-Os was found to exist over a range of some 15 atomic percent variation in solute concentration. Furthermore, the superconducting behavior of this region was found to agree with previous work on the sigma phases as to T_c and atomic volume dependence.[1] An interesting sidelight of this work was the use of superconductivity as a metallurgical tool in determining crystallinity and apparent deviations from stoichiometric composition.

[1] R. D. Blaugher and J. K. Hulm, J. Phys. Chem. Solids (to be published).

C4. Collision of Atoms with Crystal Surfaces.* N. CABRERA AND E. KINZER, *University of Virginia.*—The transfer of kinetic energy into vibrational energy of the solid has been studied on one-dimensional models, both continuum and discrete, and for normal and glancing incidence. As the collisions involve many phonon creations, classical mechanics is used throughout, following the previous work by Cabrera[1] and Zwanzig.[2] This work is extended to different masses and interactions between atom and crystal. The transfer of energy is generally easy for normal incidence but can be difficult for glancing motion providing for possible surface mobility other than diffusionlike. Furthermore, an analysis will be presented of the frequency spectrum excited in the solid, and the practical possibilities for phonon excitation will be discussed. The discrete model will be extended to accommodate the possible creation of defects in the solid (Frenkel-Kontorova model for a crowd ion). Finally, the limiting cases where quantum mechanics gives result different from classical mechanics will be pointed out.

* Work supported by the U. S. Office of Naval Research.
[1] N. Cabrera, Discussions Faraday Soc. **28**, 16 (1959).
[2] R. W. Zwanzig, J. Chem. Phys. **32**, 1173 (1960).

C5. Dielectric Breakdown Etch Dendrites on LiF Cleavage Surfaces. J. W. DAVISSON, J. PASTERNAK, AND W. H. VAUGHAN, *U. S. Naval Research Laboratory.*—Dielectric breakdown etch dendrites on LiF cleavage surfaces occur in both the ⟨100⟩[1] and the ⟨110⟩ orientation. The existence of two surface dendrites is one of many indications that the orientation of electrical breakdown paths is not determined by a discontinuous nucleation of dislocation loops. The precisely oriented ⟨110⟩ dendrite forms in regions of high electrical field strength and results from primary crystallographic surface breakdown attributable to the formation of oriented electron avalanches. The less rigorously oriented ⟨100⟩ dendrite forms in regions of low electrical field strength and depends upon environmental conditions. Its formation may result from plasma breakdown in the ambient oil over the crystal surface, and its orientation may be due to the confluence in the ⟨100⟩ directions of ⟨110⟩ electronic streamers on the crystal surface. The Y branches terminating the ⟨100⟩ dendritic arms result from primary breakdown. Thus, when primary surface breakdown occurs, the Y branches become ⟨110⟩ dendrites and when primary volume breakdown occurs, short Y branches are formed which associate with submerged, surface-parallel, incipient, ⟨110⟩ electrical breakdown paths.

[1] J. J. Gilman and D. W. Stauff, J. Appl. Phys. **29**, 120 (1958).

C6. Coloration of Potassium Chloride by Relativistic Electrons. H. SCHULTZ AND D. M. J. COMPTON, *General Atomic.**—Pulses of electrons from the General Atomic linear accelerator have been used to study the formation of color centers in potassium chloride. The maximum dose rate is 0.3 megw per cc. EPR and optical studies have been made of the concentration

of F and other centers as a function of electron energy in the range 8–20 Mev, of instantaneous dose rate, and of total dose. At room temperature the curve of concentration of F centers versus total dose shows a break at 10^{16}/cc. In the initial stages it is proportional to the instantaneous beam current. Resolved optical absorption peaks are also observed at 212, 345, and 830 mμ. The energy to form an F center is about 200 ev. In addition, an optical system has been assembled capable of observing the fluorescence and coloration during and after each pulse. A typical pulse with rise and fall time of 0.1 μsec and a length of 5 μsec produces a readily detectable F-band coloration. Studies have been made in this way of the transient behavior during the growth of F centers.

* John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic Division of General Dynamics Corporation, San Diego, California.

C7. Piezoresistivity in Oxygen-Deficient $BaTiO_3$ Single Crystals. BRENTON L. MATTES, *Lockheed Aircraft Corporation.* —Large piezoresistive coefficients were observed for oxygen-deficient $BaTIO_3$ single crystals when stress was applied in the [001] direction (c axis). The resistivity change was measured in the [100] direction (a axis). The resistivity decreased when a compressive stress was applied in the [001] direction giving a positive π_{13} coefficient. The magnitude of the π_{13} coefficient is approximately 200×10^{-12} cm²/d for a stress of 10^7 d/cm² at 25°C. The resistivity for this single crystal is 150 Ωcm. The π_{12} coefficient is an order of magnitude lower than π_{13}, but is negative. The π_{11} coefficient is positive and smaller than π_{13}. The piezoresistive coefficients are nonlinear with stress. The hydrostatic coefficient is about 200×10^{-12} cm²/d at 10^8 d/cm², but decreases to approximately 100×10^{-12} cm²/d at 10^9 d/cm². Absolute magnitudes for these coefficients could not be assigned due to hysteresis effects dependent upon applied stress and temperature. These coefficients are in agreement with the "secondary" piezoresistivity mechanism,[1] i.e., a strain-induced crystal structural change affecting the charge carrier mobility. $BaTiO_3$ has its greatest crystal structure asymmetry in the tetragonal and orthorhombic phase. Thus, in the tetragonal phase π_{13} would be greater than π_{11} and π_{12}.

[1] B. L. Mattes and L. E. Hollander, Jr., Bull. Am. Phys. Soc. 6, 139 (1961).

C8. Experimental Determination of Spin-Lattice Relaxation Time for F Centers in KCl at Low Temperatures.* D. W. FELDMAN, J. G. CASTLE, JR., AND R. W. WARREN, *Westinghouse Research Laboratories.*—Relaxation of F-center electrons has been observed in a variety of KCl crystals at liquid helium temperatures. Microwave samples were prepared by additive coloring or by γ irradiation. The source crystals included some of purified KCl.[1] The method of observation consisted of monitoring the spin resonance as a function of time after inversion.[2] Exponential recovery to thermal equilibrium described by the same, single time-constant, T_1, has been observed in several samples. For the "direct" process of relaxation, the product TT_1 was found to be 2800 sec °K. Comparison to the room temperature results[3] for NaCl will be made.

* Work supported in part by U. S. Air Force Cambridge Research Laboratories contract.
[1] R. W. Warren (to be published).
[2] J. G. Castle, Jr., P. F. Chester, and P. E. Wagner, Phys. Rev. 119, 953 (1960).
[3] W. E. Blumberg, Phys. Rev. 119, 1842 (1960).

C9. Frequency Spectrum of a Disordered Cubic Lattice. J. C. BRADLEY, *RIAS, Baltimore* (introduced by L. Witten).—A procedure was developed to compute the moments of the vibrational frequency spectrum associated with a totally disordered simple cubic lattice containing two atomic species. The $2k$th order moment of the spectrum μ_{2k} equals the trace of D^k (the kth power a matrix whose eigenvalues are the squares of the normal mode frequencies); a matrix, Σ, was developed to decompose the terms arising in a diagonal element of D^k into distinct classes of terms, thus providing a means of computing μ_{2k}. The moments were compiled through μ_{18}, and calculations of the frequency spectrum were obtained from a series expansion of the spectrum in terms of the moments. There is evidence to support a conjecture that the vibrational contribution to physical properties of a totally disordered crystal at a low temperature may be approximated by the same properties of a crystal composed of only light atoms at that temperature.

THURSDAY AT 11:00

Auditorium of the Faculty of Sciences

(FERNANDO ALBA ANDRADE presiding)

Invited Papers

CA1. Episodios de la Historia de la Física en los Estados Unidos. KARL K. DARROW, *American Physical Society.* (40 min.)

CA2. Optical Masers and Their Uses. C. H. TOWNES, *Columbia University.* (40 min.)

THURSDAY AT 11:00

Auditorium "B" of the Chemistry School

(A. C. KOLB presiding)

Chemical Physics; Fluid Dynamics I

D1. Reaction Cross Section for 160-Mev O^{16} Ions in Aluminum by the Attenuation Method.* G. IGO AND B. WILKINS, *Lawrence Radiation Laboratory, Berkeley.*—Reaction cross sections have been measured for 160-Mev O^{16} ions using the attenuation method. Briefly, the method involves the attenuation of an ion beam of intensity I_0 in a thin absorber (10% of the range of the ion) of thickness x g/cm². Under these circumstances the reaction cross section σ_R is given by the

relation $\sigma_R = (I - I_0)/n \times I_0$, where n is the number of target nuclei per cubic centimeter and I is the attenuated ion beam. The numerator is measured by the attenuation method[1] involving an anticoincidence between two 0.0002-in.-thick plastic scintillators placed before the absorber and a plastic scintillator following the absorber. The passing counters are spaced 40 in. apart and a millimicrosecond time-of-flight method is used to eliminate a low-energy tail on the incident beam which is inherent in the heavy ion accelerator beam and can also be produced by a collimator system placed before the passing counters. After passing through the time-of-flight array and the Al absorber, the ions must pass through a Au degrader before striking the rear plastic scintillator. The Au degrader discriminates against 90-Mev O^{16} ions. Since heavy-ion reactions are peaked forward, tests have been made to show that light reaction products do not trip the anticoincidence circuit.

* Supported by the U. S. Atomic Energy Commission.

D2. Reactive Scattering in Crossed Molecular Beams.* J. A. NORRIS, G. H. KWEI, J. L. KINSEY,† AND D. R. HERSCHBACH, *University of California, Berkeley.*—Angular distributions of reactively scattered alkali halides have been measured for reactions of thermal beams of K and Rb atoms with beams of several halogen-containing compounds. The apparatus used in earlier experiments[1] has been modified to enable the scattering to be studied for various angles of intersection of the incident beams. The additional data obtained by varying the intersection angle is shown to lead to a considerable improvement in the resolution obtained on transforming the laboratory angular distributions to the center-of-mass system. Also, parts of the distributions previously hidden by elastic scattering could be shifted into view by use of wide-angle intersections. In six reactions, the recoil spectrum of products shows the same general features observed before.[1] The improved resolution has shown that in the center-of-mass system the reactive scattering has a substantial asymmetry about 90°.

* Supported by the Atomic Energy Commission and the Alfred P. Sloan Foundation.
† Fellow of the Miller Institute for Basic Research in Science.
[1] G. H. Kwei, J. A. Norris, and D. R. Herschbach, Bull. Am. Phys. Soc. **5**, 503 (1960), J. L. Kinsey, G. H. Kwei, and D. R. Herschbach, *ibid.* **6**, 152 (1961).

D3. Angular Distribution of Products in Chemical Reactions.* D. R. HERSCHBACH AND J. L. KINSEY,† *University of California, Berkeley.*—Angular distributions predicted by theoretical models for chemical reaction are derived and compared with results of molecular beam experiments. Some features of models for nuclear reactions can be adapted to molecular collisions, and particular attention is given to the limiting cases represented by the "statistical" model and the "direct interaction" model.[1] The statistical model involves the assumption of a collision complex analogous to a "compound nucleus," in which the breakup of the complex would be independent of its mode of formation (aside from restrictions imposed by conservation laws). This model appears to require that the recoil spectrum of products be symmetrical about 90° in the center-of-mass system, in disagreement with the experiments. A direct interaction mechanism gives qualitative agreement. It is emphasized, however, that a rather wide class of intermediate mechanisms is compatible with the available data.

* Supported by the U. S. Atomic Energy Commission and the Alfred P. Sloan Foundation.
† Fellow of the Miller Institute for Basic Research in Science.
[1] See, for example, V. F. Weisskopf, Physica **22**, 955 (1956).

D4. Atom Recombination Rates for Atom Molecule Mixtures. ROY J. HEYMAN, *Martin-Denver.*—Classical methods have been employed to estimate the rate of atom recombination in a mixture of atoms and diatomic molecules of those atoms for a restricted temperature range. An approximated Lennard-Jones (6–12) potential is assumed to exist between any two particles and the number of three-body collisions is derived statistically. The number of such collisions resulting in recombination is determined from a maximum total collision energy criteria. The final expression for the recombination rate for diatomic gases varies as $T^{-1/6}$ times a polynomial in $1/T$ for atom-atom-molecule collision. The results are compared to the most recent experimental data reported in the literature.

D5. Derivation of the Master Equation for Dense Gases from the Liouville Equation. FRANK C. ANDREWS,* *University of California, Berkeley.*—A "generalized master equation for dense gases" has previously been shown to lead to the monotonic approach of the velocity distribution to equilibrium.[1] We here show how this equation may be formulated from the Liouville equation, clearly indicating sufficient conditions for its validity in representing the evolution of an ensemble. We study the evolution of φ_N, the complete velocity distribution function, by a generalization of methods of the Brussels group.[2] We find that our generalized master equation is valid when (a) the concentration may be considered small in some sense which we make precise, and (b) φ_N is slowly enough varying in time that we may neglect its explicit change during the duration of a collision.

* National Institutes of Health Research Fellow.
[1] F. C. Andrews, Bull. Am. Phys. Soc. **6**, 166 (1961).
[2] I. Prigogine, *Non-Equilibrium Statistical Mechanics* (Interscience Publishers, Inc., New York, to be published).

D6. Inadequacy of Newtonian Mechanics to Describe the Hydrodynamics of an Anatomical Discovery in the Arterial System. HARRY LOBEL, *Nebraska Iowa Electrical Council.*—Newton's third law has no more application to pulsating hydraulics than Ohm's law has to alternating electricity. This is demonstrated by the flow of blood. At the mouths of arteries branching from the aorta are funnel-shaped nozzles. On stimulation, these nozzles adjust their contour to streamline varying blood flows. Malfunction results in eddy currents and hydrodynamic stress. These nozzles demonstrate the inadequacy of Newton's third law. For a dynamical model, hydraulic pulsations are introduced into elastic tubes. The frequencies of pulsations are varied. At the proper frequency, pulsations become resonant. In resonance, pressure is minimum for a given flow; in "dissonance," pressure is hypertensive for the same flow. In resonance, pressure and flow are mathematically related in accordance with the third law of motion. In dissonance, the concepts of action and reaction as developed by Newton are misleading. There are two kinds of pressure in dissonance: one is a resistive pressure which does useful work; the other is a useless "reactive" pressure. The vector sum is the "impedance." Without differentiating between resistive and reactive components of pressure, no theory of hydraulics is rational. The reactive component of pressure causes stress and, when it reaches a critical values, results in turbulence.

D7. Flame Propagation in Tubes. TONY MAXWORTHY,* *Harvard University.*—An idealized theory has been formulated to explain the effects of tube diameter, mixture composition, and direction of motion on the flame shape, and "speed of uniform motion" of a flame front propagating through a stationary air-fuel mixture contained in a long tube. The effects of local flame curvature on flame speed and viscous effects within the fluid are considered, for it is believed that both play major roles in the production of a steady-state flame of finite amplitude. Ideally, it is possible to match the present theory (valid far from a real wall) to a theory, as yet unformulated, that accounts for the flame shape of the quenched portion of the flame close to the tube wall. This matching is discussed qualitatively.

* Present address: Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California.

D8. Viscous Heating in Capillary Flow. E. A. KEARSLEY, *National Bureau of Standards.*—The Hagen-Poiseuille law for capillary flow of a viscous, incompressible fluid is valid only for rates of flow for which viscous heating is negligible. Since viscosity is, to a good approximation, an exponential function of temperature, there is a strong, nonlinear coupling between the heat-balance equation and the Navier-Stokes equation. A closed solution will be displayed for the steady state flow in an infinite capillary of circular cross section with thermostated walls. The resulting corrected form of the Hagen-Poiseuille law will be shown, and results will be compared with the linearized approximation of Hausenblas.[1] These results, it will be seen, bound the thermal effects for capillary flow in a practical sense.

[1] Hausenblas, Ing. Arch. **18**, 151 (1950).

D9. Transverse Force on a Spinning Sphere Moving in a Viscous Fluid.* S. I. RUBINOW, *Stevens Institute of Technology*, AND JOSEPH B. KELLER, *Institute of Mathematical Sciences, N.Y.U.*—The flow about a spinning sphere moving in a viscous fluid is calculated for small values of the Reynolds number. With this solution the force and torque on the sphere are computed. It is found that, in addition to the drag force determined by Stokes, the sphere experiences a force $\mathbf{F}_L$ orthogonal to its direction of motion. This force is given by

$$\mathbf{F}_L=\chi a^3\rho\boldsymbol{\Omega}\times\mathbf{V}[1+0(R)].$$

Here a is the radius of the sphere, $\boldsymbol{\Omega}$ its angular velocity, $\mathbf{V}$ its velocity, ρ the fluid density, and R the Reynolds number, $R=\rho\mu^{-1}Va$. For small values of R, the transverse force is independent of the viscosity μ. This force is in such a direction as to account for the curving of a pitched baseball, the long range of a spinning golf ball, etc. It is used as a basis for the discussion of the flow of a suspension of spheres through a tube. The calculation involves the Stokes and Oseen expansions. A representation of solutions of the Oseen equations in terms of two scalar functions is also presented.

* The research in this paper was partially supported by the U. S. Office of Naval Research.

D10. Relations between Velocity and Vorticity Vector Orientations in Perfect Liquid Permanent Flows. ENZO LEVI, *Institute of Engineering, National University of Mexico.*—The Euler equation $(v\times\mathrm{rot}v)=\mathrm{grad}E$ implies that equienergetic surfaces $E=$const are at the same time flow and vortex surfaces. That the family of flow lines and that of vortex lines which cover the surface are conjugate in the Dupin involution is demonstrated. If the velocity vector orientation is known at one point in space, this relation leads to the orientation of the vorticity vector, and vice versa.

D11. MHD Flow Constructions with Fundamental Solutions. MEREDITH C. GOURDINE, *Plasmadyne Corporation.*—In this paper steady flows of an incompressible, viscous, electrically conducting fluid are constructed from fundamental solutions of magnetohydrodynamics—the applied magnetic field is parallel to the velocity at infinity. The flat plate and the sphere are considered as examples, and approximate solutions are presented for the limiting cases of large and small Reynolds and magnetic Reynolds numbers. The effects of currents in the body are also considered, and it is found that unless the magnetic Prandtl number is larger than unity, currents in the body have negligible effect on the flow.

THURSDAY AT 14:30

Auditorium of the Engineering School

(S. A. KORFF presiding)

Invited Papers in Cosmic-Ray Physics II

E1. The Present Status of Geomagnetic Theory. MANUEL SANDOVAL VALLARTA, *El Colegio Nacional and Comisión Nacional de Energía Nuclear.* (30 min.)

E2. Energy Balance in Extensive Air Showers. J. R. GREEN, *University of New Mexico.* (30 min.)

E3. Direct Measurements of Charged Particles Associated with Auroral-Zone Radio Absorption. I. B. MCDIARMID, *National Research Council, Canada.* (30 min.)

E4. Solar Cosmic Rays and Polar-Cap Ionospheric Absorption. D. K. BAILEY, *National Bureau of Standards, Boulder.* (30 min.)

E5. Cloud-Chamber Experiments on Primary Cosmic-Ray Electrons and Solar Cosmic Rays. JAMES EARL, *University of Minnesota.* (30 min.)

THURSDAY AT 14:30

Eighth-Floor Auditorium, Tower of Sciences

(M. MAZARI presiding)

Nuclear Reactions; Proton-Proton Scattering

F1. Angular Distribution in the Photodisintegration of the Deuteron.* G. KRAMER, *Lawrence Radiation Laboratory, Berkeley.*—The photodisintegration of the deuteron is calculated for γ-ray energies in the laboratory of 39.8, 52.3, 77.3, and 107.3 Mev corresponding to nucleon-nucleon scattering in the laboratory of 75, 100, 150, and 210 Mev. For the ground state the Hulthén wave function with a D-state probability $p_D=4\%$ is used. The final state interaction in the isotopic spin triplet states is calculated from the Gammel-Thaler potential and in the isotopic spin singlet states from the potential producing the Hulthén ground state wave function. The coupling of the scattered waves is taken into account exactly,

All dipole and quadrupole transitions are included. The results for the total cross section and the ratio a/b in the angular distribution for the two cases: (1) $p_D=4\%$ and (2) $p_D=6.7\%$ are compared with the experimental data. In the latter case the amplitudes as calculated by De Swart and Marshak[1] have been used.

* Supported by the Atomic Energy Commission.
[1] J. J. de Swart and R. E. Marshak, Physica **25**, 1001 (1959).

F2. The $Li^6(He^3,n)B^8$ Excitation Function.* B. J. FARMER AND C. M. CLASS, *Rice University.*—Boron-8 is unusual in that all of its excited states are particle unstable. This circumstance together with the fact that the nucleus decays by positron emission enables one to determine the total reaction cross section for forming B^8 in its ground state only, simply by measuring the yield of positrons to which this cross section is proportional. Such measurements have been carried out for B^8 made by the $Li^6(He^3,n)$ reaction in the energy interval between threshold at 2.97 and 5.5 Mev. The cross section exhibits an $(E-E_{th})^{\frac{1}{2}}$ dependence over an interval of 500 kev above threshold. Beyond, the cross section increases linearly, reaching a value of 21.5 ± 2.0 mb at 5.5 Mev. It is possible to fit the linear portion by making use of the energy dependence of the obvious dynamical factors in the expression for the reaction cross section. To do so requires the reasonable assumption that an $l=2$ diproton is captured by the Li^6 nucleus.

* Supported in part by the United States Atomic Energy Commission.

F3. The 9.63-Mev State of C^{12}.* R. R. CARLSON AND E. B. NELSON, *State University of Iowa.*—Gamma radiation from the 16.11-Mev state to the 9.63-Mev state in C^{12} has been identified with a three-crystal pair-spectrometer (4.5% resolution for 6-Mev gamma radiation) and with 6 in. long by 5 in. diam NaI(Tl) crystal detectors. The 6.45 ± 0.05-Mev line occurs with a branching ratio of 1% of the well-known 11.67 Mev -4.43 Mev cascade radiation. The 16.11-Mev state of C^{12} was obtained by bombardment of thick boron targets with protons at the 163-kev resonance for the $B^{11}+p$ reaction. The yield of 6.45-Mev radiation showed resonance at the same energy. Since the 9.63-Mev state supposedly[1] breaks up overwhelmingly ($\Gamma=30$ kev) by alpha particle emission, the 6.45-Mev line should not be accompanied by an appreciable amount of coincident gamma radiation. In confirmation, coincidence spectra taken with two detectors biased at 1.5 Mev showed no 6.45-Mev line. The angular distribution of the 6.45-Mev radiation was measured relative to that of the known 11.67-Mev radiation. Previous analysis of the data from experiments involving the 9.63-Mev level suggests that this state has a spin and parity of 3^-, and not 1^- as formerly supposed.[1] The measured angular distribution agrees with 3^- and not with 1^-.

* Supported in part by the U. S. Atomic Energy Commission.
[1] F. Ajzenberg-Selove and T. Lauritsen, Nuclear Phys. **11**, 1 (1959).

F4. Quasi-Elastic Scattering of 920-Mev α-Particles by α-Particle Clusters in C^{12}.* T. J. GOODING AND G. IGO, *Lawrence Radiation Laboratory, Berkeley.*—Direct evidence for α clusters in C^{12} has been obtained from the reaction $C^{12}(\alpha,2\alpha)Be^8$ at 920 Mev. The kinetic energies and scattering angles of the two outgoing α particles are consistent with a quasi-elastic collision of the incident α particle with an α-particle cluster in the carbon nucleus. The sum of the energies of the two outgoing α particles shows a peak at approximately the incident energy. A second peak is observed on the summed energy spectrum at about 600 Mev. Since the experimental arrangement does not distinguish between He^4 and He^3 this second peak may involve He^3 particles. We observe similar peaks in the summed energy spectrum when the α beam is scattered from helium. A comparison of the cross sections from helium and carbon determines the probability of α clusters in carbon.

* Supported by the U. S. Atomic Energy Commission.

F5. Phase Shift Analysis in the Elastic Scattering of Protons by O^{16}.† R. W. HARRIS, G. C. PHILLIPS, AND C. M. JONES, *Rice University.*—The elastic scattering of protons from O^{16} has been studied in the energy range 3.4 to 5.75 Mev using a gas target scattering chamber. Excitation curves were taken at the center of mass angles 39.23°, 63.50°, 90°, 103.46°, 114.66°, 125.27°, 131.38°, 140.77°, 149.43°, 161.28°, and 166.75°; angular distributions were measured at laboratory energies of 4.134, 4.268, 4.402, and 4.540 Mev. A phase shift analysis was done and indicates that the two broad overlapping levels of F^{17} have assignments as follows:

J^π	E_{res}	F^{17}*
$\frac{3}{2}^-$	4.26 Mev	4.60 Mev
$\frac{3}{2}^+$	4.65	4.97.

The data will be presented and the phase shift analysis will be discussed.

† Supported in part by the U. S. Atomic Energy Commission.

F6. Angular Distributions of the Ground and First Excited States of O^{17} at Moderate Energies (~1.6 Mev) in and out of an F^{18} Resonance. MARIA ESTHER ORTIZ DE LOPEZ, *Institute of Physics, National University of Mexico.*—Some investigators have observed irregularities in the angular distribution of $O^{16}(d,p)O^{17}(1)$, consisting of a remarkable increase of the cross section at higher angles, possibly associated with the formation of the compound nucleus F^{18}. In order to explain this situation, studies were carried out using a Van de Graaff accelerator and a broad-range magnetic spectrograph. The resonance energy of the compound nucleus $O^{16}+d$ was first established; angular distributions were then made at bombarding energies of 1.65 and 1.53 Mev, respectively, in and out of the F^{18} resonance ($E_x=8.99$ Mev). By comparing the experimental curves with the theoretical ones obtained by the use of the Butler theory for both incident deuteron energies it is possible to associate the values $l_n=0$ and 4 to the neutron capture momenta. Although, the background is higher in resonance than out of it, both cases show a notorious increase around 100°, (center of mass system) comparable with the intensity expected at 0°. The Butler theory seems not to be applicable in order to explain the observed shape in $O^{17}(1)$, as an angular momentum for the captured neutron $l_n=4$ is highly improbable. The $O^{17}(0)$ and $C^{13}(0)$ distributions, observed simultaneously with $O^{17}(1)$, showed no important anomalies.

F7. Broad Range Magnetic Spectrograph for Aid in the Study of Angular Distributions. J. RICKARDS, I. CASTRO, F. ALBA, AND M. MAZARI, *Institute of Physics, National University of Mexico.*—A 29-cm radius broad range magnetic spectrograph[1] has been constructed to be used as a monitor during the measurement of angular distributions. The geometry and magnetic fields achievable make possible the counting of particles elastically scattered from any nucleus on 25×5 cm photographic plates or on a scintillation crystal, with the desired peaks exempt from contaminants. It is fixed for observation at 90° with respect to the incident beam from a 2-Mev Van de Graaff generator, while a similar 40-cm radius spectrograph can rotate from 0° to 120°. This monitoring, using the scintillation counter during each run, permits the target to be changed when necessary, its thickness or deterioration and changes in the intensity of the incident beam having no effect whatsoever on the duration of the run, as this is determined by the number of particles elastically scattered by the nucleus in question. Very thin targets can thus be used,

preventing the overlapping of adjacent peaks and loss in energy when particles pass through the substance. The possibility arises of determining cross sections by means of a simple comparison with one well known value. A description of the apparatus, as well as some results, will be given.

[1] C. P. Browne and W. W. Buechner, Rev. Sci. Instr. **27**, 899 (1956).

F8. Remeasurement of Nuclear Reaction Q Values in the Light Element Region. A. TEJERA, M. MAZARI, A. JAIDAR, AND G. LOPEZ, *Institute of Physics, National University of Mexico.*—As was announced by W. W. Buechner[1] at the International Conference on Nuclidic Masses in Hamilton, Canada, a group of high Q values, which presented exceptional discrepancies as compared to those computed from the latest nuclear mass tables[2], were remeasured. Conditions of the apparatus were improved by its reorientation and by adjusting the beamwidth to coincide with that of the Po^{210} calibrator, through a reduction of five times its original width. Recalibration with Po^{210} was made without changing the magnetic field when the reaction allowed it. The higher Q values as well as other reactions simultaneously observed are reported in this paper. Experimental errors and cycle closure errors were improved. In spite of better precision there still exist discrepancies larger than the observation errors.

[1] W. W. Buechner, *Proceedings of the International Conference on Nuclidic Masses*, edited by H. E. Duckworth (University of Toronto Press, Toronto, Canada, 1960), p. 270.
[2] Everling, König, Mattauch, and Wapstra, Nuclear Phys. **15**, 342 (1960).

F9. Q Values in the Carbon-Neon Region for Precise Nuclear Mass Determinations. G. LOPEZ, *Institute of Physics, National University of Mexico,* AND O. ALMEN, *Institutionen för Fysik, Chalmers Tekniska Högskola.*—The convenience of remeasuring transition energies in the carbon to neon region under similar experimental conditions,[1] induced the group of the National University of Mexico to ask the collaboration of specialists in producing targets of gasses embedded in metallic backings. A group from the Technological University of Chalmers (Sweden) prepared targets containing the isotopes N^{15}, O^{18}, Ne^{20}, and Ne^{22}, enriched by magnetic separation. The following reactions (p,α), (d,α), and (d,p) in N^{15} and O^{18}, (d,α) and (d,p) in Ne^{20}, and (d,p) in Ne^{22} were run. Differences between the results of these tests and those reported before[2] are within the experimental errors. Only in the $N^{15}(d,\alpha)C^{13}$ and $Ne^{20}(d,\alpha)F^{18}$ reactions the values obtained are, respectively, 19 and 25 kev lower than those reported. These discrepancies are approximately three times greater than the experimental errors.

[1] W. W. Buechner, *Proceedings of the International Conference on Nuclidic Masses*, edited by H. E. Duckworth (University of Toronto Press, Tornto, Canada, 1960), p. 264.
[2] F. Ajzenberg-Selove and T. Lauritsen, Revs. Modern Phys. **27**, 77 (1955); and Nuclear Phys. **11**, 1 (1959).

F10. Excitation Level Energy Determinations of the Light and the First Intermediate Nuclei through (d,p) and (d,α) Reactions. A. JAIDAR, G. LOPEZ, M. MAZARI, AND R. DOMINGUEZ, *Institute of Physics, National University of Mexico.*—In the systematic study of Q-value measurements for accurate mass determinations undertaken by the group at UNAM,[1] using Van de Graaff and broad range magnetic spectrograph techniques, a good number of particle groups corresponding to excited states of nuclei appeared in the surveyed region. The analysis of this information confirmed, in most cases within the experimental errors, the excitation energies of previously reported levels. The following list shows a summary of the observed energy levels of each residual nucleus for which the differences between values obtained and those published before are smaller than the sum of experimental errors: Li^7(1), B^{11}(1 to 3 and 8 to 11), B^{12}(1), C^{12}(1 and 2), C^{14}(1), N^{15}(1, 2 and 5), O^{17}(1 to 10), O^{19}(1), Ne^{21}(1 to 7), Ne^{23}(1 and 3), Na^{24}(1 to 7 and 13 to 17), Mg^{27}(1), Al^{28}(1 to 13), Si^{29}(1 to 12), Si^{30}(1 to 3), P^{30}(2 and 3), Si^{31}(1), K^{40}(1 to 3, 6, 7, 10, 14 and 15). Discrepancies in the spectra greater than the sum of errors, were observed in the following nuclei: C^{13}, Mg^{25}, Mg^{26}, and S^{32}.

[1] M. Mazari *et al.*, *Proceedings of the International Conference on Nuclidic Masses*, edited by H. E. Duckworth (University of Toronto Press, Toronto, Canada, 1960), p. 276.

F11. Stripping Analysis of the $Fe^{54}(d,p)Fe^{55}$ Reaction.* A. SPERDUTO, W. W. BUECHNER, H. A. ENGE, AND J. RAPAPORT, *Massachusetts Institute of Technology.*—The MIT-ONR Van de Graaff accelerator and broad-range spectrograph were used to study angular distributions of protons emitted from a thin target of iron enriched in Fe^{54} to 96.7%. The bombarding energy was 7.5 Mev. Some preliminary results of the stripping analysis up to an excitation energy of 3 Mev in Fe^{55} are as follows:

Ex (Mev)	0	0.413	0.931	1.316	1.921	2.051	2.144	4.474	2.944	3.03
l_n	1	1	3	(3)	1	1	3	1	(1)	1

Groups corresponding to levels at 1.410, 2.210, 2.302, 2.542, 2.581, 2.877, and 2.988 do not show typical stripping distributions. Analysis of additional levels above 3 Mev will be reported.

* This work has been supported in part with funds provided by the U. S. Atomic Energy Commission, by the Office of Naval Research, and by the U. S. Air Force Office of Scientific Research.

F12. Stripping Analysis of the $Ni^{62}(d,p)Ni^{63}$ Reaction.* H. A. ENGE, W. W. BUECHNER, J. R. ERSKINE, J. A. TAYLOR, H. J. HENNECKE, AND A. SPERDUTO, *Massachusetts Institute of Technology.*—The MIT-ONR Van de Graaff accelerator and the new multiple-gap, broad-range spectrograph[1] have been used to study angular distributions of protons emitted from a thin enriched Ni^{62} target bombarded with 7.01-Mev deuterons. The excitation energies and the l values for the captured neutron are for the lowest states:

Ex (Mev)	0	0.085	0.155	0.513	0.995
l_n	1	3	1	1	1

* This work has been supported in part with funds provided by the U. S. Atomic Energy Commission, by the Office of Naval Research, and by the U. S. Air Force Office of Scientific Research.
[1] H. A. Enge and W. W. Buechner, Bull. Am. Phys. Soc. **6**, 253 (1961).

F13. Proton-Proton Collisions at 3.5 Bev.* T. C. ANDREWS, R. M. KALBACH, AND R. J. PISERCHIO, *University of Arizona.*—A stack of 50, 10×10×0.06 cm, G-5 emulsion pellicles was exposed to an external, 3.5-Bev proton beam of the Berkeley bevatron. Both area scanning and the method of secondary track following[1] were employed to locate a total of 1116 nuclear interactions of beam protons. Of these interactions, 115 were found to satisfy the kinematics of proton-proton collisions. Correction for collisions with bound protons included in this sample was made through an analysis of peripheral proton-neutron interactions. The most probable inelastic proton-proton interaction was found to be one which results in two charged secondaries. Angular distributions and momentum spectra of secondary protons and pions, determined from a combination of multiple scattering, range, and blob density measurements, will be reported.

* Supported by the National Science Foundation.
[1] R. M. Kalbach, J. J. Lord, and C. H. Tsao, Phys. Rev. **113**, 325 (1959).

F14. Proton-Proton Collisions at 4.2 Bev.* M. H. BLUE, J. J. LORD,† J. G. PARKS,† AND C. H. TSAO,† *Lawrence Radiation Laboratory, (Livermore).*—Interactions between 4.15-Bev protons and the free hydrogen nuclei in nuclear emulsion are examined. The cross section for elastic scattering was 11.6±2.6 mb, determined from 27 events. Based on 113 interactions the inelastic cross section was 28.1±3.1 mb. The partial cross

sections corresponding to inelastic collisions having two, four, six, and eight secondary particles were respectively 16.3±2.4, 11.5±1.8, 0.2±0.1, and 0.1±0.1 mb. Although the total inelastic cross section varies slowly with energy, the partial inelastic cross sections were found to be strongly energy dependent. The observed angular distribution of elastically scattered protons in the center of mass system was sharply peaked in the forward and backward directions, in reasonable agreement with calculations based on an optical model applicable for energies between 2 and 10 Bev. Particles produced in inelastic collisions were identified as pions or protons by measurements of energy loss and multiple scattering. For those particles identified, center of mass system distributions of energy, angle, and transverse momentum are presented.

* Supported by the National Science Foundation and by the joint program of the U. S. Atomic Energy Commission and the Office of Naval Research.

† University of Washington, Seattle, Washington.

F15. Scattering of 5.1-Bev Protons in Nuclear Emulsion.* C. H. TSAO, J. G. PARKS, AND J. J. LORD, *University of Washington.*—Over 500 nucleon-nucleon collisions including large angle one-prong scatterings have been found by following the light secondaries as well as the primaries. They were selected on the basis that they showed no sign of nuclear disturbance such as nuclear recoil or evaporation tracks as well as on the basis of kinematic accredibility. A total of 34 elastic-like p-p events were measured along with an equal number of quasi-elastic events. Based only on the findings from scanning through 240 m of primary tracks the elastic p-p cross section was found to be about 8 mb and the inelastic cross section 29 mb. There is no evidence of elastic charge exchange p-n scattering indicating a probable maximum charge exchange cross section less than 1.4 mb. The inelastic p-n cross section was found to be comparable to that for p-p scattering. The angular distribution of the one-prong events is in general agreement with that predicated by diffraction theory but is found to be much smaller in the angle interval between 0.5° to 1°. Momentum and angular distributions of the secondary particles emitted from inelastic scattering will be presented.

* Supported by the National Science Foundation, and by the joint program of the U. S. Atomic Energy Commission and the Office of Naval Research.

THURSDAY AT 14:30

Auditorium of the Faculty of Sciences

(J. M. HOUSTON presiding)

Symposium of the Division of Electron Physics

Physics of Thermionic Energy Conversion

FA1. The Physics of the Plasma Diode Energy Converter. W. B. NOTTINGHAM, *Massachusetts Institute of Technology.* (25 min.)

FA2. Comparison of an Actual and an Idealized Thermionic Energy Converter. N. S. RASOR, *Atomics International.* (25 min.)

FA3. Space-Charge Instabilities in Cesium Plasmas. K. G. HERNQVIST, *RCA Laboratories.* (25 min.)

FA4. Spectroscopic Measurements of Cesium Plasmas. LEWIS AGNEW, *Los Alamos Scientific Laboratory.* (25 min.)

FA5. Thermionic Emission of Metal Single Crystals in Alkali-Metal Vapors. H. F. WEBSTER, *General Electric Research Laboratory.* (25 min.)

THURSDAY AT 14:30

Auditorium of the Chemistry School

(J. W. DAVISSON presiding)

Semiconductors

G1. Hall Mobility in Zinc-Doped Germanium. D. C. CRONEMEYER, *Bendix Research Laboratories.*—Although zinc-doped germanium has important low-temperature photoconductive properties, the zinc concentration in such p-type crystals is difficult to obtain from 25°C Hall-coefficient measurements because of the strong magnetic-field dependence of the Hall coefficient. The interpretation of Hall-coefficient data is straightforward only for large magnetic fields. Previous Hall-coefficient measurements made on zinc-doped germanium using magnetic fields of the order of 0.2–0.7 webers/m² did not achieve saturation at 25°C. For the measurements reported here, carefully calibrated magnetic fields were employed ranging up to 2.1 webers/m², sufficient to obtain essentially saturation Hall-coefficient values at 25°C even for lightly doped samples. Most of the measurements were performed upon elongated rectangular plates; the experimental values were corrected for end-shorting and magnetoresistance. Several bridge-shaped ultrahomogeneous samples were also measured in order to assure the absence of electrode and resistivity gradient effects. Data concerning the Hall coefficient, Hall mobility, and magnetoresistance variations with magnetic field at 25°C for zinc concentrations ranging from 10^{14}–10^{17} cm^{-3} are presented in this paper.

G2. Effective Mass of Electrons and Holes in PbTe. K. F. CUFF, M. R. ELLETT, AND C. D. KUGLIN, *Lockheed*

Research Laboratory.—From measurements of the thermoelectric power, high field Hall coefficient, and the energy dependence of the carrier scattering relaxation time, the density of states effective mass m_D has been determined as a function of temperature for electrons and holes in PbTe. In the 80–300°K temperature range, the values of m_D change approximately linearly with temperature and show little dependence on carrier concentration for samples from 4×10^{17}–9×10^{18}/cm³. Below 50°K, the values of m_D indicate a dependence upon carrier concentration, which becomes very pronounced at 10°K. These results will be interpreted in terms of both the change in band gap with temperature and the possible existence of other energy minima in both the conduction and valence bands, in addition to the established ⟨111⟩ minima at the zone edge.[1,2] The low-temperature results will be compared to the effective mass values obtained from oscillatory phenomena.

[1] C. D. Kuglin, M. R. Ellett, and K. F. Cuff, Phys. Rev. Letters **4**, 177 (1961).
[2] P. J. Stiles, E. Burstein, and D. N. Langenberg, Bull. Am. Phys. Soc. **6**, 115 (1961).

G3. Excitons and Band Splitting in CdTe. D. G. Thomas, *Bell Telephone Laboratories.*—Transitions to an $n=1$ exciton state have been seen in reflection in spectra of vapor and melt grown cubic crystals of CdTe between 77° and 1.6°K. These results and also absorption data appear to be consistent with a minimum band gap at $\mathbf{k}=0$ between *s*-like conduction and *p*-like valence bands. The degeneracy of the top $P_{\frac{3}{2}}$ valence band has been lifted by applying uniaxial compressive stress in the [001], [111], and [110] directions. The single exciton reflection peak splits into two peaks; for both [001] and [111] stress, the peak that moves to higher energies is active only for light polarized perpendicular to the stress direction, while the other peak is active in both polarizations. Thus the $M_J=\pm\frac{1}{2}$ band moves "up" and the $M_J=\pm\frac{3}{2}$ band moves "down". Splittings of 15×10^{-3} ev have been produced by stresses of about 1200 kg/cm². Three deformation potentials can be obtained. As the $n=1$ state derived from the $M_J=\pm\frac{3}{2}$ band crosses the continuum of the exciton from the $M_J=\pm\frac{1}{2}$ band, the transition broadens due to rapid autoionization. The binding energy of the $M_J=\pm\frac{1}{2}$ band exciton is thus crudely estimated to be 0.008 ev.

G4. Rectification and Tunneling Effects in Oxide Films on Reduced Single-Crystal Rutile (TiO_2) and Ti Metal. Lewis E. Hollander, Jr., and T. J. Diesel, *Lockheed Aircraft Corporation.*—The rectification and tunneling properties of thin TiO_2 films have been investigated. Measurements on thin (1 μ) single-crystal films anodized on both the "*a*" and "*c*" crystallographic planes indicate a large difference in oxygen vacancy mobility but similar rectification characteristics. In order to obtain rectification in rutile, a steep gradient in the oxygen-vacancy density must be achieved. It is inferred that the rectification occurs at the TiO_{2-x}–TiO_2 interface. Tunneling effects have been observed at room temperature in thin (100–200 A) anodized films on titanium metal, as evidenced by a negative-resistance region occurring in the current-voltage characteristic between 0.2–0.5 v. This characteristic was symmetrical. Tunneling effects have not, as yet, been observed in anodized single-crystal rutile.

G5. Theory of Tunneling in a Longitudinal Magnetic Field. P. N. Argyres, *Lincoln Laboratory,* MIT.*—We have developed a quantum-mechanical theory of the effect of a longitudinal magnetic field on the tunneling in certain solids. The study of this effect requires the careful elimination of the interband matrix elements of the interaction of the electron with the magnetic field. This is accomplished by finding the eigenfunctions of the electron in the periodic potential and the magnetic field by a method closely related to that of Yafet.[1] The interaction with the electric field is now separated in its intraband and interband effects, the bands now being the ones in the presence of the magnetic field. The intraband effects are treated exactly, and first-order, time-dependent perturbation theory is used to examine the tunneling process for small electric fields. Application of this theory is made to the tunneling among the two conduction and the two light hole valence bands in InSb. The effects of spin and spin-orbit interactions have been taken into account. The matrix elements that determine the tunneling probabilities among the various bands are evaluated by the saddle-point method and compared to each other.

* Operated with support from the U. S. Army, Navy, and Air Force.
[1] Y. Yafet, Phys. Rev. **115**, 1172 (1959).

G6. Radiation Induced Hump Structure in Current-Voltage Characteristics of Esaki Tunnel Diodes.* C. B. Pierce, H. H. Sander, and A. D. Kantz, *Sandia Laboratory.*—The current-voltage characteristics of Ge, Si, and GaAs Esaki tunnel diodes all show a growth of well-defined hump structures in the excess current region when irradiated at low temperatures (80°–200°K) with 2-Mev electrons. The growth of excess current at a given bias is linear with total flux for flux that does not induce excessive heating. Diodes irradiated at room temperature or higher also show a linear increase in excess current, but without hump structure, while diodes developing structure with low-temperature irradiation continue to show the structure at room temperature. With increasing dose, the first hump in particular Ge tunnel diodes rises much faster than does the "normal" excess current. With sufficient dose, this hump may rise to more than twice the original peak current, with a negative resistance range following the hump having a greater dynamic range than existed originally. Two humps have been located in Ge and GaAs, and three humps in Si. These may be related to energy levels in the forbidden gap. Capacity changes are noted following the growth of hump structure. The bias voltages at which humps appear in the different types of tunnel diodes are shown.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

G7. Alternating Current Field Effect Measurements in a Magnetic Field. Norman G. Einspruch, *Texas Instruments Incorporated.*—High resistivity (40 Ω-cm *n*-type) germanium surfaces which had been exposed to a modified CP-4 etch and subsequently stored in air, were studied by means of ac field-effect measurements in which the dimensionless surface potential was varied over the range -2.25 to $+1.25$ by the capacitively applied sinusoidal electric field. The analysis of Kingston and Neustadter[1] was used to evaluate the density of induced charge trapped in surface states. Further ac field-effect measurements were made in the presence of a transverse external magnetic field[2]; the field-effect mobility varied from 1.9×10^3 (*p*-type) to 2.2×10^3 (*n*-type) cm²/v sec as H was varied from zero to 9.00 koe in both normal and reverse senses. Measurements have been made on illuminated surfaces of 400 Ω-cm *p*-type silicon which had been similarly treated. The conductance minimum has been observed as well as characteristic *p*-type shifts in surface potential upon exposure to dried O_2. Measurements of the field-effect mobility performed in a magnetic field indicate that the magnetic field causes similar variations in the surface transport properties as was observed for germanium.

[1] R. H. Kingston and S. F. Neustadter, J. Appl. Phys. **26**, 718 (1955).
[2] Aerts, Amelinckx, and Vennik, J. Electronics and Control **VII**, 497 (1959); E. Aerts, J. Electronics and Control **IX**, 217 (1960).

G8. Precision Length Change Measurements on Electron Irradiated Germanium.* Frederick L. Vook, *Sandia Laboratory.*—Precision measurements of the change in length of high-purity, single-crystal germanium were made on irradia-

tion and annealing. Two samples were irradiated with 2-Mev electrons at temperatures $<365°K$ and $<86°K$, respectively. The first sample was irradiated at 33 $\mu a/cm^2$ to an integrated flux of 5.4×10^{19} electrons/cm^2. The specific length expansion obtained was $\Delta L/L=6.2\pm12.2\times10^{-26}$ per 2-Mev electron/cm^2. The 86°K sample was irradiated at 10 $\mu a/cm^2$ to an integrated flux of 3.0×10^{19} electrons/cm^2. The specific length expansion obtained was $1.5\pm3.9\times10^{-25}$ per 2-Mev electron/cm^2. Using the Seitz-Koehler simple theory of displacement ($E_d=30$ ev) and assuming no annealing at the low temperature, we calculate a concentration of displaced pairs equal to 1.6×10^{-3}. The corresponding fractional atomic-volume change of isolated interstitial vacancy-type defects in germanium is such that $(f_i+f_v)=0.008\pm0.021$ or <0.03; i.e., considerably smaller than that found for the more clustered defects formed in deuteron irradiated germanium.[1] These results indicate that the volume annealing, starting at 200°K in deuteron irradiated germanium, is due to the rearrangement or motion of interstitial vacancy clusters.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

[1] F. L. Vook and R. W. Balluffi, Phys. Rev. **113**, 62 (1958).

G9. Recombination Processes in Far-Infrared Photoconductors. GERALD S. PICUS, *Hughes Research Laboratories.*—The conductivity, Hall effect, photoresponse, and noise in germanium doped with Zn, Cu, and In have been measured at 4.2°K as a function of applied electric field and incident background photon flux in an effort to better understand the free-carrier generation-and-recombination processes that determine the behavior of these materials as detectors of far-infrared radiation. The I-V characteristic shows a high field breakdown independent of photon flux coincident with that observed in 4.2°K dark. At intermediate values of electric field, the current varies as $I=I_0(\exp V/V_0-1)$, where I_0 is proportional to the incident photon flux and V_0 is approximately 0.4 of the critical breakdown voltage. For low fields, the sample is ohmic with conductivity proportional to incident photon flux. The equivalent short circuit signal current i_s, observed in response to a constant additional radiation input (small compared to the background flux) is proportional to the bias current I in the low and intermediate field regions and falls off at high fields. The fields at which the ratio i_s/I begins to decrease is believed to be an accurate indication of the onset of impact ionization generation of free carriers. A qualitative model explaining the results in terms of the variation with electric field of the sticking probability of a carrier in the excited states of a giant trap[1] has been developed.

[1] M. Lax, Phys. Rev. **119**, 1502 (1960).

G10. Qualitative Discussion of the Semiconductor Bond and Its Importance in Epitaxial Growth. E. C. HUEBSCHMAN, *Convair Astronautics.*—The characteristics of the atomic orbitals in relation to semiconductivity are discussed and illustrated by a table of atomic orbitals. The lattice parameter of crystals which are related to atomic orbitals are investigated in epitaxial growth. The bond type is also considered and seemed to be the more important parameter.

G11. Sputtering of an Intermetallic Compound Semiconductor.* S. P. WOLSKY AND E. J. ZDANUK, *Raytheon Company* (introduced by W. C. Dunlap).—A sensitive quartz microbalance in ultra-high vacuum has been used to study the argon ion bombardment of single-crystal GaSb. This compound was chosen for investigation because of the ~2/1 ratio of the masses of the individual elements. Sputtering yields have been measured over an energy range of 100–1500 ev for different crystal orientations. The yields of the (111) and $(\bar{1}\bar{1}\bar{1})$ faces were found to be similar. The preliminary data indicates a maximum in the sputtering yield near 1200 ev with a decrease in the yield at higher energies. The data is explained in terms of the recent theories applying radiation damage concepts to sputtering.

* The research reported in this paper has been supported, in part, by the Electronics Research Directorate of the Air Force Division, ARDC.

Invited Paper

G12. Title and speaker to be announced.

THURSDAY AT 14:30

First-Floor Auditorium, Tower of Sciences

(HENRY MARGENAU presiding)

Theoretical Physics I

H1. Gaussian Wave Functions for Polyatomic Molecules.* FRANK E. HARRIS, *Stanford University.*—Convenient mathematical expressions have been devised for the discussion of polyatomic molecules in terms of one-electron wave functions of the form $r^{2n+l}Y_l^m(\theta,\varphi)\exp(-\alpha r^2)$, where Y_l^m is a spherical harmonic and (r,θ,φ) are polar coordinates about any point (not necessarily the same point for different one-electron functions). The expressions presented are designed to be suitable for automatic computation. Progress in computations with these functions will be reported.

* Supported in part by the National Science Foundation.

H2. Symmetry-Adapted Functions Belonging to the Cubic Group. JOE SCHLESSINGER AND HAROLD V. MCINTOSH, *RIAS.*—A program is being prepared for the IBM 7090 computer which will permit the calculation of symmetry adapted functions belonging to certain groups according to methods outlined in recent papers.[1] The program parameters are the name of the group and the set of functions to be adapted; and a prior knowledge of the group characters or representations is not required. The techniques are illustrated with respect to the symmetry group of the cube.

[1] Harold V. McIntosh, J. Math. Phys. **1**, 453–60 (1960); J. Mol. Spectroscopy **5**, 269–283 (1960).

H3. Representations of Markov Processes. I. OPPENHEIM, *Convair, San Diego,* AND K. E. SHULER, *National Bureau of Standards.*—Conditional probabilities for Markov processes obey the Smoluchowski-Chapman-Kolmogoroff equation (S-C-K). We demonstrate that under a wide variety of conditions, solutions of the S-C-K equation are also solutions of the master equation and that solutions of the master equation

must be solutions of the S-C-K equation. The relationship between the S-C-K equation and the Fokker-Planck (F-P) equation is discussed. The derivation of the F-P equation from the S-C-K equation involves the condition that the 3rd and higher moments of the distribution function can be neglected compared to the lower moments. The class of stochastic processes described by the F-P equation is a subclass of the Markov processes which are described by the S-C-K or the master equation. For certain classes of Markov processes, e.g., Gaussian Markov processes, the master equation and the F-P equation are identical.

H4. Stochastic Processes in Linear Harmonic Chains. K. E. SHULER, *National Bureau of Standards*, AND I. OPPENHEIM, *Convair, San Diego.*—We discuss the dynamics of a particle in an ensemble of linear harmonic chains with N particles of equal mass. This forms an example of a stochastic system which is non-Markovian in that its temporal behavior can not be described by a master equation. We have derived explicit expression for $n_\epsilon(t)d\epsilon$, the fraction of particles with energy between ϵ and $\epsilon+d\epsilon$, at time t for the limiting cases $t\to\infty$, $N\to\infty$ $(t\gg N^2)$; $t\to\infty$, $N\to\infty$ $(N>t)$; and $t\to 0$ $(t\ll N)$. The behavior of this system is contrasted with the stochastic process which describes the motion of a heavy particle in a linear harmonic chain. In a statistical ensemble of such chains, the temporal behavior of the heavy particle is represented by a Gaussian Markov process in the displacement and the velocity.[1]

[1] R. J. Rubin, *Proceedings of the International Symposium on Transport Processes in Statistical Mechanics*, edited by I. Prigogine (Interscience Publishers, Inc., New York, 1958); J. Math. Phys. 1, 309 (1960).

H5. Generation and Testing of Markoff Signals. G. KURZ DE DELARA, A. ELGUEZABAL, AND I. SCHNADOWER, *Comisión Nacional de Energía Nuclear.*—Following a new method of design,[1] a generator of a Markoff signal having an alphabet of three symbols has been built. Starting from a radioactive sample as a Poissonian source, a controlled correlation, both in quality and quantity, is introduced in order to provide, within wide limits, a Markoff process having a preassigned transition matrix. The signals have been tested, compared with theory, and found to reproduce the prescribed statistics within the expected error limits. The purpose of the instrument is to provide a well-defined adjustable Markoffian signal for use in simulation, computation, prediction, filtering, and correlation analysis. Particular emphasis is laid upon processes having periodic irreversible asymptotic forms.

[1] A. Medina, "Time-dependent logic" (personal communication to be published).

H6. Invariant Imbedding: A New Approach to Transport Processes. RICHARD BELLMAN, *The Rand Corporation* (introduced by S. S. Friedland).—The usual Boltzmann approach to the study of neutron transport processes and radiative transfer leads to functional equations of linear or nonlinear type with boundary conditions in the space variables. The functional equation technique of invariant imbedding, extending and generalizing work of Ambarzumian and Chandrasekhar, leads to nonlinear functional equations with initial values in both space and time variables. These equations are more readily treated computationally by means of a digital computer, afford a new analytic approach, and allow one to take account of more realistic physical features. Similar techniques can be applied to wave processes.

H7. General Relativitity in a Pseudo-Weyl Space. F. ROHRLICH, *University of Iowa*, T. FULTON, *Johns Hopkins University*, AND L. WITTEN, *RIAS.*—Maxwell's equations, the Lorentz force equation,[1] the classical Dirac equation, as well as Einstein's gravitational field equations can be generalized from a Riemann to a Weyl space. If the characteristic vector occurring in Weyl's linear connection is a gradient (pseudo-Weyl space), the gravitational-field equations are still of second order. This generalization makes the classical laws manifestly conform invariant and in particular invariant under metric gauge transformations, $g_{\mu\nu}'=\sigma g_{\mu\nu}$. This invariance requires that rest masses transform with $\sigma^{-\frac{1}{2}}$ and the gravitational coupling constant with σ. The physical meaning of this invariance will be discussed.

[1] Schouten and Haantjes, Proc. Ned. Akad. Wet. 39, 1063 (1936); *ibid.* 43, 1288 (1940).

H8. Radiation Reaction in Linear Theories of Gravitation.* PETER HAVAS, *Lehigh University.*—Recently, a study of the effects of gravitational radiation reaction in general-relativity theory was undertaken[1]; the motion of a two-body system was investigated using the author's Lorentz-invariant approximation method, and the system was found to gain energy. To check this unusual result, a similar study has been carried out for the linear theories of gravitation of Belinfante and of Birkhoff (as generalized by Barajas, Graef Fernández, and Kustaanheimo). Radiation reaction terms were introduced into the equations of motion of these theories by the usual special relativistic methods. In Belinfante's theory, the amount of energy lost or gained by a two-body system was found to depend on his adjustable constants; if these are chosen to give the correct perihelion advance, an energy gain almost equal to that found in general relativity is obtained. No comparable result is attainable in Birkhoff's theory, because it does not permit a satisfactory definition of energy. Some implications of these results for the problem of gravitational radiation will be discussed.

* Research supported by the National Science Foundation.
[1] S. F. Smith and P. Havas, Bull. Am. Phys. Soc. 5, 53 (1960).

H9. On Imaginary Numbers in Quantum Mechanics. E. J. SCHREMP, *U. S. Naval Research Laboratory.*—Møller, Synge, and others have suggested using two distinct symbols i and j for the respective imaginary elements ($i^2=j^2=-1$) of special-relativity theory and of quantum mechanics, since logically these need not be the same. A basic criterion for distinguishing them, apparently unnoticed heretofore, is indeed available, as may be seen from the following considerations. We have previously characterized free baryons (and antibaryons) by the symmetry property[1] $\psi_\pm=(Y/|Y|)i\psi_\pm e$, where Y is hypercharge and e is a real quaternion unit vector ($e^2=-e_0$). Now, any elementary plane wave $\psi_\pm$ (or its G conjugate) is here ultimately defined by the equations $\partial\psi_\pm/\partial x^k=(p_k/\hbar)\psi_\pm e$, where $p_k=\text{const}\,(k=0,1,2,3)$ and p_0c, the energy, is *always positive*. But by the above symmetry property, these equations become $\partial\psi_\pm/\partial x^k=-j(p_k/\hbar)\psi_\pm$, where $j=(Y/|Y|)i$ is $+i$ or $-i$ for baryons (and antibaryons) of positive or negative hypercharge Y, respectively. For other elementary particles and their antiparticles, an analogous fundamental definition of j in terms of i is also possible. The broad quantum-mechanical implications of this result will be discussed.

[1] E. J. Schremp, Bull. Am. Phys. Soc. 5, 81 (1960); NRL Quart. Nuclear Sci. and Tech., January 1960 (unpublished), pp. 26–35.

H10. Tensor Virial Theorem, Variation Method, and the Correlation Problem. DAVE PANDRES, JR., *The Martin Company.*—Let ψ be an eigenfunction of the Hamiltonian H for a system containing N identical particles with positions $\mathbf{r}_i$ and momenta $\mathbf{p}_i$. If ψ describes a bound state, it satisfies a quantum analog of Parker's tensor virial theorem[1] which states that the diadics $\langle\psi|[\sum_i\mathbf{r}_i\mathbf{p}_i,H]|\psi\rangle$ and $\langle\psi|[\sum_{i\neq j}\mathbf{r}_i\mathbf{p}_j,H]|\psi\rangle$ vanish. An approximate eigenfunction ϕ must also satisfy this theorem if it accurately describes a discrete energy state. We show that this requirement may be fulfilled by a variational calculation using a generalization of Fock's scaling method.[2] Let

$\phi = \Lambda F(\mathbf{R}_1, \ldots, \mathbf{R}_N)$ where $\mathbf{R}_k = \Sigma_i \alpha_{ki} \cdot \mathbf{r}_i$ and Λ is the appropriate projection operator for fermion or boson wave functions. The tensor virial theorem is automatically fulfilled when $\langle \phi | H | \phi \rangle$ is minimized with respect to the scaling parameters α_{ki}. This method of introducing variation parameters into a trial wave function may be regarded as a generalization of Shull and Lowdin's open-shell method,[3] allowing angular as well as radial correlations in the particle motions.

[1] E. N. Parker, Phys. Rev. **96**, 1686 (1954).
[2] V. Fock, Z. Physik **63**, 855 (1930).
[3] H. Shull and P. O. Lowdin, J. Chem. Phys. **25**, 1035 (1956).

H11. Unified Theory of Electromagnetics and Dynamics A. KYRALA, *Arizona State University and Motorola, Inc.*—From a definition of mass (energy) m as an integrating factor of the Pfaffian form $c^2dt - \mathbf{v} \cdot \mathbf{dR}$ associated with the Minkowskian metric $c^2dt^2 - \mathbf{dR} \cdot \mathbf{dR}$ the dynamical equations $\partial_t(m\mathbf{v}) + \nabla(mc^2) = 0$ and $\nabla \times (m\mathbf{v}) = 0$ are obtained as the conditions for unique integrability. In case these equations are not satisfied, the zeros on the right sides must be respectively replaced by two vectors $\mathbf{E}$ and $-\mathbf{H}$ which may then be considered to be defined by the left sides. It is then easily verified that these vectors satisfy Maxwell's equations provided that electrical charge q and current $\mathbf{J}$ (densities) be defined by $q = \partial_t(\nabla \cdot m\mathbf{v}) + \Delta(mc^2)$ and $-\mathbf{J} = \partial_t \nabla(mc^2) + \partial_t^2(m\mathbf{v}) + \nabla \times \nabla \times (m\mathbf{v})$. The so defined charge is conserved. The assumption of conservation of mass(energy) density m then yields the conclusion that charge density q is the D'Alembertian of mass (energy) density m. By generalizing m to a corresponding probability density of localization of mass(energy) in terms of a complex wave function ϕ, a quantum-mechanical translation of the unified electromagnetic-dynamic theory with expressions for $\mathbf{E}$, $\mathbf{H}$, q, and $\mathbf{J}$ in terms of operations on ϕ and ϕ^* is obtained.

H12. Another Form of Quantum Electrodynamics PETER RASTALL, *University of British Columbia.*—It is shown that electrodynamics may be quantized in a straightforward fashion if one first slightly modifies the field equations by adding to them certain functions of a scalar operator. The additional terms are proportional to a parameter f which may be made to tend to zero after the quantization. No use is made of an indefinite metric. The theory is invariant with respect to general c-number gauge transformations, and is equivalent in the interaction picture to that of Novobátsky and Valatin.

H13. Experimental Demonstration of Geometry and Particle Concept. JOSEPH G. BARREDO, *C.S.I.C.*—The chrono-superconductivity effect, predicted by triondynamics and demonstrated by nanosecond techniques, proves that the physical concept of charge is more general than any geometrical concept. This effect demonstrates also: (1) Rieman's prediction[1] that only by experiment can we prove which kind of space is real. (2) Even Rieman's geometry, which embraces Euclidean's and Bolyai-Lobachevski's geometries as particular cases, is too naive to deal with real space. (3) The geometrical concepts in which Einstein's invariance $ds^2 = dx^2 + dy^2 + dz^2 - cl^2$ and Lorentz's transformation are based do not correspond to real space, thus, these equations are practical approximations only. (4) The internal contradictions of quantum-electrodynamics exclude it from explaining high-energy phenomena since quantum electrodynamics tries to define physical concepts in terms of geometric concepts and not vice versa. (5) Rossi's MIT group will observe cosmons of cross section $<10^{-52}$ cm^2 producing cosmic rays of energy $>10^{19}$ ev at the rate of less than one/year with the present equipment.

[1] W. K. Clifford, Proc. Cambridge Phil. Soc. **2**, 157 (1876); J. G. Barredo, Bull. Am. Phys. Soc. **6**, 306 (1961).

THURSDAY AT 14:30

Auditorium "B" of the Chemistry School

(S. A. SCHAAF presiding)

Fluid Dynamics II

HA1. On the Stability of a Shear Layer in a Magnetic Field.* J. MENKES, *California Institute of Technology.*—It is demonstrated that a uniform magnetic field in a direction normal to the mean flow has a stabilizing influence. A disturbance which propagates with fixed maximum amplitude in the absence of a magnetic field is shown to be damped once the field is applied. The degree of damping is proportional to the Alfvén speed. This confirms a result obtained earlier by Stuart[1] for the case where the magnetic field is aligned with the mean flow. For the case of infinite conductivity, the flow is absolutely stable for arbitrarily small magnetic fields.

* This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration.
[1] J. T. Stuart, Proc. Roy. Soc. (London), **A221** (1954).

HA2. Analog Solution of the Real Gas Flat Plate Laminar Boundary Layer Problem. SHERMAN J. FENSTER AND ROY J. HEYMAN, *Martin-Denver.*—A REAC Analog Computer has been used to solve the real gas flat plate laminar-boundary layer problem. The method employs the "local similarity" concept and an extension of the ideas developed by Lee's and Fay and Riddell. The effects of diffusion through the boundary layer and various degrees of recombination in the boundary layer and at the surface are included. The final heat-transfer equation is independent of a Lewis number parameter since a variable Lewis number was employed in the conservation equations. The heat-transfer parameter $\mathrm{Nu}/(\mathrm{Re})^{\frac{1}{2}}$ was correlated from the numerical solution and found to be of the form $\mathrm{Nu}/(\mathrm{Re})^{\frac{1}{2}} = a_1(\rho_e\mu_e/\rho_w\mu_w)^b$, frozen flow, and $\mathrm{Nu}/(\mathrm{Re})^{\frac{1}{2}} = a_2(\rho_e\mu_e/\rho_w\mu_w)^b$, equilibrium flow, where a and b are constants. An important conclusion drawn from the analysis is that the heat transfer through a frozen boundary layer to a fully catalytic wall is almost twice that of an equlibrium boundary layer. Application of the above relations readily produces expressions for the heating rates in terms of the free stream velocity, the enthalpy difference, and the $\rho\mu$ ratio across the boundary layer.

HA3. Hot-Wire Measurements in Hypersonic Flow. T. VREBALOVICH, *California Institute of Technology.*—The hot-wire technique for measuring fluctuations in supersonic flow has been extended to hypersonic flow in the 21-in. Jet Propulsion Laboratory hypersonic wind tunnel where the stagnation temperatures can be as high as 1400°F. New materials had to be employed to construct probes which could withstand the temperatures encountered in the hypersonic tunnel. Preliminary results indicate that at a Mach number of 8.5, supply pressure of 1000 cm Hg, and supply temperature of 850°F, the mass flow fluctuations in the free stream are about 2.5% and the total temperature fluctuations are nearly 0.2%. This result compares well with low supersonic speed free stream measurements extrapolated to this Mach number.

The 0.00005-in. wire operates in the free molecular flow regime where recovery factors greater than one should be attained for a long, radiation shielded wire, but in the above case the wire recovery temperature was less than the stagnation temperature. A sizable fraction of the heat transferred from the wire is conducted into the supports and radiated to the cold tunnel walls so that the support temperature must be measured and large corrections must be applied to the heat loss laws in order to interpret the measurements.

HA4. Turbulent Diffusion and Pair Density. RICHARD BOURRET, *Hughes Research Laboratories* (introduced by G. F. Smith).—The pair-density function for a passive inertialess diffusate is constructed from formal solutions of the equation of continuity by taking ensemble averages of the product of solutions at two different space points. The assumptions are made that (1) the velocity distribution of the fluid substratum transporting the diffusate is Gaussian and (2) that the fluid velocity is statistically independent of all the spatial derivatives of the initial diffusate distribution. A parabolic diffusion equation for the pair-density function is obtained in which the effective diffusivity is dependent upon both the spatial and temporal scale of the process through the space-time velocity autocorrelation function for the fluid motion. This last is estimated in two different ways and the consequences for the diffusion of pair density discussed. A comparison with the inductive-dimensional theory of L. F. Richardson is made.

HA5. On the Process of Cascading of Energy from a Primary Vortex to Motions of Higher Wave Numbers. JOHN R. WESKE AND TOM M. RANKIN, *University of Maryland*.—Spontaneous decay of primary vortices, such as those which arise during transition of boundary layer flow from the laminar to the turbulent regime, was found to originate under certain conditions of which a divergence of the vortex tube is foremost. The required magnitude of the rate of steady or nonsteady enlargement of the vortex core necessary to induce decay of primary vortex motion was computed. On this basis two controlled experiments, one for steady flow the other for a transient occurrence, were devised. Their outcome not only confirmed previous observations, they also made possible detailed evaluation of the sequence of events giving rise to motions of a broad spectrum of higher wave numbers. Certain favored wave numbers were determined numerically from flow measurements. This process and the associated mixing motions were rendered observable by appropriate techniques of visualization. A 16 mm film will be presented illustrating the physical details of the cascading effect, the controlled experiments and the quantitative results derived.

HA6. Cavitation Bubble Collapse in Water with Finite Density Behind the Interface.* MAURICE HOLT AND NATE J. SCHWARTZ, *University of California, Berkeley*.—The collapse of an empty cavity in water has been treated by Hunter,[1] using a similarity solution. Conditions for similarity require that the value of the density of water at the cavity boundary is zero, although the value corresponding to zero pressure given by the Tait equation of state is nonzero. To satisfy the correct boundary conditions on the cavity surface, Hunter's similarity solution is perturbed to take account of first-order changes in the wall density. The perturbation equations are integrated numerically to determine the cavity-wall velocity and the flow field in the disturbed water.

* Supported by the Office of Naval Research.
[1] J. of Fluid Mech. **8**, 241 (1960).

HA7. Effect of Ambient Pressure and Temperature on Air Shock. JANE DEWEY, *Ballistic Research Laboratories*.—In agreement with recent work of Ericsson and Edwin,[1] experiments[2] in a chamber in which pressure and temperature simulate conditions at altitudes to 60 000 ft were in general agreement with Sachs's scaling. Sachs assumes that peak pressure and positive impulse depend only on the total energy of detonation. With Hopkinson scaling of distance and time with charge dimensions, this leads to the prediction that P/p_0 and $Ic_0/(W^{\frac{1}{3}}p_0^{\frac{1}{3}})$ are functions of $p_0^{\frac{1}{3}}R/W^{\frac{1}{3}}$ alone. P and p_0 are the peak and ambient pressures, I positive impulse, c_0 sound velocity in the ambient air, R the distance from a charge of mass W. Shock velocity and piezoelectric measurements covered the range of distances from 4 to 25 ft/lb$^{\frac{1}{3}}$, ambient pressures from $\frac{1}{10}$ to 1 atm, and temperatures of -55°C to 25°C. Since P/p_0 is independent of p_0 at the charge surface Sachs's relations cannot be general. Recent normally reflected impulse measurements at 0.5 to 3 ft/lb$^{\frac{1}{3}}$ give results independent of ambient pressure at low pressures.

[1] U. Ericsson and K. Edin, Phys. Fluids **3**, 893 (1960).
[2] J. Dewey and J. Sperrazza, Ballistic Research Laboratories' Rept. No. 721 (1950).

HA8. Nonsteady Processes in Shock Tube Aerothermodynamic Studies. R. W. RUTOWSKI AND D. E. BUTTREY, *Lockheed Aircraft Corporation*.—The use of a shock tube for aerothermodynamic studies of interactions between supersonic gas flows and models placed in the shock tube is limited by several nonsteady phenomena which occur. The problem becomes aggravated with the use of a monatomic gas, like argon, at high-shock Mach numbers. Flow blockage, shock wave attenuation, and thermal losses due to radiation from the shock heated gas are discussed and experimental data are presented.

HA9. Duration of the Slow Nitric Oxide Decomposition Regime behind Shock Waves around 3000° K and Its Relation to the Rate Coefficient of the Exchange Path NO+O → N+O$_2$.* K. G. P. SULZMANN AND C. B. LUDWIG, *Convair-San Diego*.—An analysis of the chemical mechanisms governing the first and slow nitric oxide decomposition regime behind shock waves around 3000°K is provided. The duration of the slow decomposition regime turns out to be essentially inversely proportional to the rate coefficient governing the exchange path NO+O → N+O$_2$. Comparison of calculated values for the time duration based upon $k=2.03\times10^{10}T^{\frac{1}{2}}\exp(-38\,100/RT)$ cm^3 mole^{-1} sec^{-1} with experimental shock tube results shows agreement within 50% for temperatures between 2250° and 3450°K. This result implies the validity of the pre-exponential temperature dependence $T^{\frac{1}{2}}$ suggested by Davidson[1] for the high temperature extrapolation of the values of k determined by Kistiakowsky and Volpi[2] around 500°K.

* This research was ARGMA sponsored.
[1] N. Davidson, AVCO Research Rept. No. 32 (1958).
[2] G. B. Kistiakowsky and G. G. Volpi, J. Chem. Phys. **27**, 1141 (1957).

HA10. Ramifications of the Concept of Electron Drive in Shock Tubes. RICHARD G. FOWLER, *University of Oklahoma*.—Recently a new mechanism has been suggested by which the superthermal electrons generate the first flows observed in electric shock tubes and related devices. This mechanism has been found to be plausible both theoretically[1] and experimentally.[2] Further consideration of the mechanism shows that it has implications beyond those presented hitherto. It can explain the anomalous positive-ion conductivity in the electric shock tube,[3] the unexpected magnetic insulation in the magnetically insulated shock tube,[4] and may give insight into the problem of plasma injection from the electric shock tube and even planetary nebular expansion.

[1] R. G. Fowler and B. D. Fried, Phys. Fluids **4**, 767 (1961).
[2] R. G. Fowler, G. W. Paxton, and H. G. Hughes, Phys. Fluids **4**, 234 (1961).
[3] M. Sakuntala, A. von Engel and R. G. Fowler, Phys. Rev. **118**, 1459 (1960).
[4] R. G. Fowler and E. B. Turner, Phys. Fluids **4** 544 (1961).

HA11. Exploding Foil Production of Plane Wave Shocks and the Equation of State of Mylar.* J. R. PENNING, JR., AND D. V. KELLER, *Boeing Airplane Company*.—The high pressures produced by the confined explosion of thin metal foils are being used to accelerate thin plates to high velocities

(~0.1 cm/μsec). The slapper plates are either driven directly out of a larger sheet or else placed upon an intermediate attenuator sheet and "spalled off." After a free run to relieve internal pressures, the slapper plate impinges upon a stationary target plate and a plane uniform high-pressure shock propagates into the target. The slapper velocity and the particle velocity behind the shock in the target are measured with standard pin tecnhiques. If the equation of state of the slapper is known, the Rankine-Hugoniot equations determine a point on the Hugoniot equation of state of the target. In other experiments, the unknown is placed on a target of the same material as the slapper and thus interacts with a known material in a stressed state. In a typical experiment, the slapper is accelerated by the explosion of a 2-×2-×0.0005-in. aluminum foil from the discharge of a 15-μf, 20-kv condenser. Using these techniques, the dynamic equation of state has been measured for Mylar from comparison with Lucite and aluminum.

* Supported in part by the Air Research and Development Command, U. S. Air Force.

HA12. Peak Pressure and Duration Modifications from Reflection of Spherical Shock Waves. J. D. SHREVE, *Sandia Laboratory.*—The theoretical work of Von Neumann with computational extensions by Polachek and Seeger has led to a concise description of pressure multiplications expected from the regular reflection of plane shock waves. For the Mach reflection region, theoretical efforts to describe shock behavior have been inadequate. Theory is especially tenuous when spherically divergent shocks are encountered. To empirically document spherical shocks in both regular and irregular reflection, a field experiment was performed by the Sandia Laboratory. Centrally detonated 250-lb TNT spheres were exploded at a sequence of heights above ground to vary systematically the wavefront striking angle with shock strength. Pressure-time measurements on the reflecting surface (the ground) compared with corresponding free air-pressure values allow construction of so-called reflection charts which indicate reflected pressure as a function of incident pressure and incidence angle. Also, pressure multiplication factors as they vary with wave strength and angle are given explicitly and are contrasted with the plane wave case. A like portrayal of consequences of the reflection process is shown for positive pressure durations.

HA13. Cratering by a Megaton Surface Burst. R. L. BJORK AND H. L. BRODE, *The Rand Corporation.*—The early stages of the ground motion caused by a megaton surface burst are well described by the compressible hydrodynamic equations. Reducing the required space variables to 2 by using axial symmetry, these equations were solved numerically on an electronic computer to give this paper's results. The appropriate air overpressure as a function of space and time were imposed on the ground surface as well as the direct action of the bomb debris. The ground's equation of state was approximated by fitting the theoretical Fermi-Thomas-Dirac results, the experimental results in the 80 to 300 kbar range, and the sound velocity. The pressure and velocity fields calculated to occur in the ground are presented as a function of space and time. The results show that the bomb debris is the primary agent for both crater formation and the underground waves beneath the crater, rather than the previously supposed air overpressure. At horizontal distances substantially greater than the crater radius, the air overpressure dominates the motion.

HA14. Hugoniot Equation of State of Granite.* DAVID B. LOMBARD AND FRANK L. ADELMAN, *Lawrence Radiation Laboratory, Livermore.*—The Hugoniot equation of state of granite has been measured by Alder and Lombard[1] at the Lawrence Radiation Laboratory; work has also been done at Stanford Research Institute by Grine.[2] High explosive systems were used to generate shocks up to 884 kbar. Several methods of measuring particle velocity and shock velocity have been employed. The resulting dynamic equation of state is well defined above 330 kbar, but for shocks of lower amplitude, reproducibility is poor. It is suggested that experimental inaccuracies have been introduced by the presence of a large elastic precursor, nonhydrodynamic behavior of the granite at lower stress levels, and multiple shock structures induced by polymorphic transitions in the constituent minerals.

* Work was performed under auspices of the U. S. Atomic Energy Commission.

[1] David B. Lombard, "The Hugoniot equation of state of rocks," UCRL-6311 (1961).

[2] D. R. Grine, "Dynamic strength of rocks," 29th Shock and Vibration Symposium, Office Naval Research Oakland, California (1960).

HA15. Shock Tube Studies of Vaporation Rates in Liquids. E. TERNER, *Armour Research Foundation* (introduced by Walter Roth).—The determination of vaporization rates in the unsteady case offers considerable theoretical difficulties, since this transient process of phase change occurs essentially under nonequilibrium conditions. In order to clarify the nature of the phenomenon and to determine the essential relevant parameters involved, experiments were carried out with a shock tube containing various liquids in the driver section. In this tube, the liquid can be heated to 500°F under pressure to avoid boiling; bursting of the shock tube diaphragm allows the heated compressed liquid to suddenly expand within the driver section. As the pressure drops below saturation pressure, the liquid vaporizes, discharging into the driven section. Suitable instrumentation allows the determination of the transient-state variables within this section and an attempt is made to deduce vaporization rates from those measurements by relating them to a simple theoretical model devised to account for the observations. In particular, comparison is made between the behavior of an assumed isentropic process and the actual nonisentropic behavior of the liquids undergoing phase change, in order to ascertain the extent to which simplifications can be introduced in the theoretical model.

FRIDAY AT 10:00

Auditorium 7, "B" Building, Centro Médico

(L. S. G. KOVASZNAY presiding)

Symposium of the Division of Fluid Dynamics

J1. Reactive Flows. HOWARD W. EMMONS, *Harvard University.* (30 min.)

J2. Rarefied-Gas Dynamics. S. A. SCHAAF, *University of California, Berkeley.* (30 min.)

J3. Plasma Column in a Pulsed Magnetic Field. A. C. KOLB, *U. S. Naval Research Laboratory.* (30 min.)

J4. Laminar Theory of Collision Free Shock Structure. CATHLEEN H. MORAWETZ, *New York University.* (30 min.)

FRIDAY AT 10:00

Auditorium 3 (C.M.)

(F. E. PRIETO presiding)

Strange Particles and Mesons

K1. Antiproton-Proton Cross Sections at Low Energy.* BRUCE CORK, ORIN I. DAHL, DONALD H. MILLER, ARNIN G. TENNER,† AND CHING LIN WANG, *Lawrence Radiation Laboratory, Berkeley.*—Interactions of a separated beam of antiprotons have been detected using the Alvarez 15-in. diam. liquid hydrogen bubble chamber. The momentum of the incident beam was 750 Mev/c and various absorbers were used to permit cross-section measurements at four energy intervals. The residual range of antiprotons in the chamber is 60 Mev. Approximately 4000 antiprotons were incident on the chamber at each of four energies and 200 elastic-scattering events were observed in each interval. Preliminary values of the cross sections are

T (Mev)	40	80	145	245
$\sigma_{elastic}$ (mb)	120	80	65	55
$\sigma_{annih.}$ (mb)	...	165	120	80
$\sigma_{ch.\ ex.\ +\pi^0}$ (mb)	60	20	15	10

The 145-Mev and 245-Mev measurements are in good agreement with the results of Coombes *et al.*,[1] and the differential elastic cross sections agree within statistics with the calculations of Ball and Fulco.[2]

* Work done under the auspices of the U. S. Atomic Energy Commission.
† Presently at Naturkundig Laboratorium Der Universitet van Amsterdam, Amsterdam, Holland.
[1] C. A. Coombes, B. Cork, W. Galbraith, G. R. Lambertson, and W. A. Wenzel, Phys. Rev. 112, 1303 (1958).
[2] J. S. Ball and J. R. Fulco, Phys. Rev. 113, 647 (1959).

K2. Estimate of the *S*-wave Σ^--n Interaction.* ORIN I. DAHL, NAHMIN HORWITZ, DONALD H. MILLER, JOSEPH J. MURRAY, AND J. SCHWARTZ, *Lawrence Radiation Laboratory, Berkeley.*—In a systematic study of 8000 absorptions of slow K^- mesons in the Lawrence Radiation Laboratory deuterium bubble chamber, 1700 events of the type $K^- + d \rightarrow \Sigma^- + \pi^+ + n$ were observed. In general, a kinematic fit cannot be made to these events because of the poorly determined Σ^- momentum. Therefore, detailed study has been confined to those events in which the Σ^- comes to rest and is captured. Independent of the length of the Σ^-, there is no bias in detecting these events because of the presence of the π^+. So far 212 capture events have been analyzed. Two quantities are of interest: (a) the momentum spectrum of the captured Σ^-'s (well determined experimentally because of the range measurement); (b) the fraction of Σ^-'s undergoing capture. Both these quantities may be calculated by using the final-state interaction model[1,2] for various strengths of the Σ^--n interaction. We find that the Σ^- momentum spectrum is adequately fitted if the *S*-wave scattering length is assumed to be 0 to 0.5 f. The corrected observed capture ratio 0.13 ± 0.02 is somewhat less than the 18% expected. Possible sources of the disagreement will be discussed.

* Work done under the auspices of the U. S. Atomic Energy Commission.
[1] R. Karplus and L. Rodberg, Phys. Rev. 115, 1058 (1959).
[2] T. Kotani and M. Ross, Nuovo cimento 14, 1287 (1959).

K3. Interaction and Decay of K_2^0 Mesons in Hydrogen.* E. L. HART, D. LUERS,† I. S. MITTRA, W. J. WILLIS, AND S. S. YAMAMOTO, *Brookhaven National Laboratory.*—The Brookhaven 20-in. hydrogen bubble chamber has been exposed to a beam of K_2^0 mesons produced by 1.25 Bev/c π^- mesons. The K_2^0 mesons were made in a polyethylene target at an angle of 47°. The 80 000 pictures taken contain about one event per 150 frames. The K_2^0 momentum varies from 200–500 Mev/c. The kinematics allow positive identification of the interactions leading to K_1^0 mesons, and the states $\Lambda^0\pi^+$, $\Sigma^0\pi^+$, $\Lambda^0(\Sigma^0)\pi^+\pi^0$, $\Sigma^+\pi^+\pi^-$, and $\Sigma^-\pi^+\pi^+$. The ratios of these cross sections will be given, and their bearing on the $\bar{K}p$ scattering lengths discussed. A certain fraction of the decays has been identified. The most easily identified case is the K_{e3} mode, which we intend to analyze for charge asymmetries, and momentum and angular distributions.

* Research performed under the auspices of the U. S. Atomic Energy Commission.
† On leave from Max-Planck-Institut für Physik, Munich, Germany.

K4. The K^--p Interaction in the 400-Mev/c Region.* R. TRIPP, M. FERRO-LUZZI, AND M. WATSON, *Lawrence Radiation Laboratory, Berkeley.*—Several thousand $\bar{K}^-$-p elastic, charge exchange, and hyperon production reactions at incident K^- laboratory momenta in the vicinity of 350, 390, and 440 Mev/c are being analyzed in order to establish the nature of the anomalous K^--p interaction in this momentum region. Preliminary results bear out the general features previously observed with a few hundred events.[1] The elastic scattering at 390 Mev/c is consistent with $1+3\cos^2\theta$ with an indication also of a slight forward peaking. The charge exchange scattering is 8 ± 1 mb. at 390 Mev/c (being several times larger than at 300 and 500 Mev/c) and with an angular distribution resembling elastic scattering. The production of Σ^+ predominates over Σ^-, a reversal from the lower-energy behavior in these channels. Strong $\cos\theta$ and $\cos^2\theta$ terms are observed in the Σ^+ production angular distribution, whereas the Σ^- production is nearly isotropic. The $\Lambda 2\pi$ channel is strongly enhanced in this momentum region.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] P. Nordin, UCRL-9489.

K5. Test of Charge Symmetry of K^+ and K^0 Mesons. J. BUTTON, F. CRAWFORD, AND M. L. STEVENSON, *Lawrence Radiation Laboratory,* M. BLOCK, A. ENGLER, R. GESSAROLI, A. KOVACS, C. MELTZER, AND D. ONLEY, *Duke University**, R. KRAEMER, M. NUSSBAUM, A. PEVSNER, AND P. SCHLEIN, *Johns Hopkins University.*†—A test of the charge symmetry of the K^+ and K^0 mesons has been made by comparing the reactions (a) $\pi^+ + d \rightarrow p + \Lambda$(or Σ^0) $+ K^+$ and (b) $\pi^- + d \rightarrow n + \Lambda$ (or Σ^0) $+ K^0$. Beams of positive and negative pions at 1.23 Bev/c were directed into the 72-in. bubble chamber, filled with liquid deuterium. About 140 events in the π^+ film and approximately three times that many in the π^- film have been measured. The cross sections for processes (a) and (b) were found to be the same within 20%. Distributions in momentum and angle of the lambdas and of the K mesons and also lambda decay asymmetries have been compared. No large deviations from charge symmetry have been observed.

* Supported in part by the Office of Naval Research.
† Supported in part by the Office of Scientific Research.

K6. Experimental Limit for $\sigma(d+d \rightarrow \mathrm{He}^4+\pi)$ at 460 Mev.* JOHN A. POIRIER, WILLIAM C. BOWMAN, JIM B. CARROLL, AND MORRIS PRIPSTEIN, *Lawrence Radiation Laboratory, Berkeley.*—A beam of 460-Mev deuterons from the 184-in. cyclotron was scattered from an extended gaseous deuterium target. Since the reaction $d+d \rightarrow \mathrm{He}^4+\pi^0$ has a two-body final state, the mass, angle and momentum of the π^0 can be inferred from observing only the mass, angle, and momentum of the alpha particle. Alpha particles at a laboratory angle of $8\frac{1}{2} \pm \frac{1}{2}$ deg were focussed by a quadrupole magnetic lens system into an array of scintillation counters. The

mass and charge of the alphas were overdetermined by measuring the momentum, time of flight, dE/dx pulse height in two counters, and range of the particles. A two-standard deviation limit of 23×10^{-34} cm²/sr was obtained for the differential angular cross section of the reaction at 90 deg in the center of mass system. This measurement is of interest because the reaction is forbidden by the conservation of isotopic spin. From a theoretical prediction of the cross section assuming that isotopic spin need not be conserved, we conclude that isotopic spin is at least 93.5% conserved (again using a two-standard deviation limit on experimentally measured quantities).

* This work was done under the auspices of the U. S. Atomic Energy Commission.

K7. (Abstract withdrawn.)

K8. Neutron Spectrum From Stopped π^- Interactions.* A. G. Barkow, C. Edmund, and F. Penaranda, *Marquette University*, G. Kane, *Manhattan College*, and Z. O'Friel, *St. Bonaventure University*.—A stack of 36 (2×4)-in. 600μ G-5 emulsions were exposed to the π^- beam of the cyclotron at the University of Chicago. The pion flux was 4×10^4 π's per cm² per min, the stopped μ^- contamination was less than 1%, and the neutron background was less than 2% by isotropy measurement of the knock-on protons. A line spectrum of neutrons is detected after scattering by a continuous spectrum of protons extending from zero to the full neutron energy, with all intermediate energies equally probable. The neutrons after scattering have an energy spectrum similar to that of the protons. By differentiating the knock-on proton spectrum, one can obtain the spectrum of neutrons produced in π^- interactions. The results of some 2500 events will be given. The data has been programed for the IBM-650. A total of 10 000 tracks will be measured since the experimental curve of knock-on protons must be sufficiently well determined so that it can be differentiated.

* Work supported by the National Science Foundation.

K9. Search for a Spin-1 Meson in Neutral-Pion Photoproduction.* Michael J. Moravcsik, *Lawrence Radiation Laboratory, Livermore*.—If a spin-1 meson existed, it could act as an intermediate particle in a meson current graph for neutral-pion photoproduction where ordinarily such a diagram is absent. Such an intermediate spin-1 meson would produce a pole in the momentum transfer plane which, for intermediate meson masses up to at least three pion masses, would be by far closer to the physical region than the conventional singularities in neutral-pion photoproduction. Thus an extrapolation of neutral-photopion differential cross sections at a fixed energy could indicate whether or not such a pole exists. The strength of the pole has been calculated for vector and pseudovector intermediate mesons, assuming that even for a spin-1 particle the residue is given by the Born approximation. Presently available data on neutral-pion photoproduction have been analyzed, and experimental requirements for the detection of a spin-1 meson for various values of its mass, anomalous magnetic moment, and coupling constant to nucleons have been specified. Results will be presented at the meeting.

* Work done under the auspices of the U. S. Atomic Energy Commission.

K10. Study of Cosmic-Ray Muon Interactions by Direct Momentum Loss Measurements in Thick Layers.* Seth H. Neddermeyer and Stanley B. Curtis, *University of Washington*.—The muon-electron collision process[1] as well as bremsstrahlung and direct pair production in nuclear collisions can be studied indirectly by magnetic deflection measurements of momentum losses in thick layers of low and of high atomic number materials. If the contributions of these processes can be identified in such measurements, there is also the prospect of using this type of measurement to investigate unknown processes that might be present. A 28-cm lead absorber was placed between two cloud chambers in an 11 000-gauss field. Photographs were taken using simple coincidences to give a random sample of sea-level particles. A second run, requiring high pulses in one or both of two proportional counters, in the middle and below the lead, sampled mainly those particles undergoing substantial energy losses in addition to the probable collision loss. The first set of data shows fluctuations around the normal collision loss of about the magnitude to be expected from the errors of measurement. The second set shows excess losses superimposed on the rather broad error distribution which are qualitatively consistent with expectations from the electromagnetic events of muons.

* Work supported by the Office of Naval Research.
[1] R. F. Deery and S. H. Neddermeyer (to be published).

K11. Cosmic-Ray Muon Interactions; Results.* Stanley B. Curtis and Seth H. Neddermeyer, *University of Washington*.—Momentum loss measurements have been made[1] on 194 tracks selected by simple coincidences and on 235 selected by the high-pulse requirement. The former represents essentially the normal flux, and the latter a 2% selection. The over-all error in $1/p$ is approximately Gaussian, with a standard deviation $(25\ \text{Gev})^{-1}$ as determined by zero field tracks. From the known error in each chamber, a band may be constructed about the curve of the normal probable fractional collision loss, as a function of initial momentum, representing a specified probability for an observation falling outside the band. Of the low pulse data, 23% lie above, and 20% below, a band chosen *a priori* to represent a 15–20% level; for the high-pulse data, 34% lie above and 16% below. If the former is taken as a rough empirical measure of the true error level, then 11% of the high-pulse data represent appreciable fractional losses above the normal collision loss, or about 0.2% of the total number of particles traversing the chamber in the momentum interval 1–20 Gev. Bremsstrahlung is the only known process that can account for some of the higher fractional losses in the high-momentum region.

* Work supported by the Office of Naval Research.
[1] See preceding abstract.

Invited Paper

K12. Summary of Initial Results Obtained with the Brookhaven Alternate Gradient Focusing Synchrotron. S. J. Lindenbaum, *Brookhaven National Laboratory*. (30 min.)

FRIDAY AT 10:00

Auditorium 4 (C.M.)

(S. S. HANNA presiding)

Metals; Magnetism

KA1. Noble Metals Grown as Small Spherical Single Crystals. M. C. WITTELS AND F. A. SHERRILL, *Oak Ridge National Laboratory.**—In an effort to develop metal crystals with a higher degree of perfection, a new technique has been employed in growing single crystals of Cu, Ag, Au, and some of their alloys. The surface-tension properties of these metals lend themselves, in varying degree, to the formation of small single crystal spheres from the melt when the crystals are free to grow without the external constraints of a crucible containment shell, except for point contact on a nearly planar surface, thereby producing excellent specimens for transmission x-ray diffraction studies. The minimum of handling necessary diminishes the dangers of distortion and deformation that could introduce crystal imperfection. The small masses of these crystals make them ideal for radiation-damage studies resulting from nuclear exposure by greatly minimizing the problems of induced radioactivity. One aspect of these studies is to examine the diffraction properties of single crystal Au in which considerable percentages of Hg have been introduced as a result of transmutation. The high cross section for the reaction makes it possible to produce 25 wt % Hg in a few months in a facility of the Oak Ridge Research Reactor.

* Oak Ridge National Laboratory is operated by Union Carbide Corporation for the U. S. Atomic Energy Commission.

KA2. Electron Relaxation Times in a Copper Single Crystal from Ultrasonic Measurements.* J. D. GAVENDA AND B. C. DEATON, *The University of Texas.*—The attenuation of ultrasonic waves in a copper single crystal has been measured in the frequency range from 10 to 110 Mc/sec as a function of magnetic field intensity and direction at 4.2°K. Longitudinal and transverse modes along the [001] and [110] directions were used. The high-field limiting values of attenuation indicate that the relaxation times for electrons in "belly" orbits are about 60% as long as relaxation times for electrons in "bow tie" orbits. These measurements are part of a program for a detailed study of the Fermi surface and electron relaxation times in copper using the ultrasonic technique. The automatic data recording apparatus which is used in conjunction with a high-speed computer for data analysis will be described.

* Supported in part by grants from The University of Texas Research Institute and the National Science Foundation.

KA3. Low-Frequency Internal Friction in Zinc Single Crystals. J. M. ROBERTS* AND N. BROWN, *University of Pennsylvania* (sponsored by T. W. Bonner).—The stress-amplitude-dependent internal friction of zinc single crystals was measured in the frequency range 10^{-1} to 10^{-2} cps. This was accomplished by direct measurement of the hysteresis loop with a capacitance strain gauge. The effect of crystal orientation, prestrain, and stress bias on the energy loss was measured. Measurements were performed at 223° and 296°K. The results were found to be in quantitative agreement with the Granato-Lücke theory of stress-amplitude-dependent internal friction and semiquantitative agreement with the Teutonico-Granato-Lücke theory. The work by Read on zinc in the kilocycle range was also analyzed. Interpretation of the results in terms of the theory of Weertman is also considered. No one theory seems adequate to explain all aspects of the results, and possible models which do so are discussed.

* Now Assistant Professor in Mechanical Engineering at the William Marsh Rice University, Houston, Texas.

KA4. Internal Friction Peaks of Cold-Worked Gold and Copper. S. OKUDA* AND R. R. HASIGUTI, *University of Tokyo* (introduced by T. W. Bonner).—The internal friction and dynamic modulus of gold (99.999%) and copper (99.99%) deformed at room temperature and liquid-nitrogen temperature was measured as a function of temperature from −165° to 100°C by the inverted torsion pendulum method. Three internal friction peaks were found in this temperature range. These peaks grew and decayed during the process of annealing and at the same time the pronounced dynamic modulus changes were observed. These results are explained by the pinning of dislocations by single interstitials, divacancies and single vacancies, which were formed during the prior deformation. A relaxation mechanism based on a point defect-dislocation interaction model is proposed to explain these internal friction peaks. In this model, a dislocation line lying along a close-packed direction containing a pinning point, breaks away from the pinning with the help of thermal energy. The point defect left behind jumps after the displaced dislocation and pins it down again. The motion of dislocation and point defect in the dislocation core is discussed in detail.

* Now at Eilliam Marsh Rice University, Houston, Texas, on leave from the Institute of Physical and Chemical Research, Tokyo.

KA5. Fission Fragment Damage in Cold Films. R. K. HART AND K. L. MERKLE, *Argonne National Laboratory* (introduced by Warren J. McGonnagle).—Transmission electron microscopy has been applied to oriented evaporated gold films. The irradiation was carried out at 60°C and the fission source was either uranium sheath metal or films of evaporated uranium dioxide under pile neutron irradiation. The damage observed was in the form of dark spots which were between 20 and 300 A in diameter. Of the spots >100 A some have the form of dislocation loops while others show a more complex internal structure. Many spots occur in the form of clusters (up to 1000 A in size), which indicates that each cluster is due to the action of a single fission fragment. The density of the spots depends on the mean energy of the fission fragments and is a factor of 10 larger than the density of fission fragments in a gold film of 500-A thickness after irradiation with 2.5×10^{12} fission fragments per cm^2 from bulk uranium. Upon annealing at 400°C for 1 hr most of the defects have disappeared. The remaining defects are tetrahedra of stacking faults.

KA6. Evaporated Titanium and Zirconium Films: Sorption Characteristics for Dry Air and Oxygen below 10^{-4} Torr. E. J. ZDANUK AND S. P. WOLSKY, *Raytheon Company* (introduced by W. C. Dunlap).—The sorption characteristics of evaporated films of titanium and zirconium for dry air and oxygen were studied in the pressure range from 10^{-8} to 10^{-4} torr by the dynamic Wagener technique. A stepwise pressure increase procedure was used to introduce gases into the reaction chamber. The electrical resistance of some of the films

was monitored during the film formation and during the gas exposure. The thinner films showed large change in resistance during gas exposure. Film thicknesses estimated from initial film resistance and bulk metal resistivity ranged from 10 to 1 $\mu g/cm^2$. Ion gauge pumping was measured and taken into account to obtain true sorption rates. An omegatron mass spectrometer was used to determine the composition of the residual gases, the introduced gases, and the ambient gas in contact with film after sorption. Initial gettering rates and changes in the gettering rates and in the sticking coefficients with amount of gas sorbed were determined. Difference between results found in this work with that reported in the literature are discussed.

KA7. A Quantitative Theory for the Dislocation Multiplication During the Early States of the Formation of Glide Bands.* H. WIEDERSICH, *Atomics International* (introduced by S. P. Harris).—The theory is based on the model of double cross-slip suggested by Johnston and Gilman.[1] Moving screw dislocations undergo cross-slip but return in a random fashion into slip planes parallel to the original slip planes. The edge dislocation parts created between the two cross-slip events can not follow the screw dislocations, thus creating dipole dislocation trails. If the distance between the dipole dislocations is large enough so that they pass each other under the applied stress, a new dislocation loop is formed in the parallel plane and the original dislocation is restored. Expressions for the number of trials and for the number of new loops created are derived. The results of the theory are found to be in good agreement with the measurements on dislocation multiplication in LiF by Johnston and Gilman.[2]

* Supported by the U. S. Atomic Energy Commission.
[1] W. G. Johnston and J. J. Gilman, J. Appl. Phys. **31**, 632 (1960)
[2] W. G. Johnston and J. J. Gilman, J. Appl. Phys. **30**, 129 (1959).

KA8. The Electrical Resistance of Alpha Hydrogen-Palladium.* W. T. LINDSAY, JR.† AND F. W. PEMENT,‡ *Westinghouse Bettis Atomic Power Laboratory.*—Electrical resistance measurements of gas-charged alpha hydrogen-palladium alloys have been made in the range 100° to 400°C. The fractional increase of palladium resistance caused by addition of hydrogen is proportional to hydrogen concentration. The constant of proportionality is independent of temperature, indicating that Matthiessen's rule is inapplicable to this system. When the results of this work are combined with those of previous authors, all of the data can be adequately represented in the range 75° to 400°C by the equation $(R/R^0)-1=(2.41\pm0.04)m$, where R is the resistance of alpha hydrogen-palladium, R^0 is the resistance of hydrogen-free palladium, and m is the hydrogen-to-palladium atom ratio.

* Work supported by the U. S. Atomic Energy Commission.
† Present address: Westinghouse Research Laboratories, Pittsburgh 35, Pennsylvania.
‡ Present address: Department of Chemistry, University of Pittsburgh, Pittsburgh 13, Pennsylvania.

KA9. Variable-Mu Ferrite Magnetometer.* T. N. HATFIELD† AND FRED MORRIS, *Electro-Mechanics Company.*—The variation of the permeability of a ferrite core with change in magnetic field is the basis of a magnetometer developed for high sensitivity and easy readout. A unique method of temperature compensation makes temperature control unnecessary. The sensitivity is less than one-tenth gamma for a fixed instrument and one gamma for a portable instrument.

* Sponsored by U. S. Air Force Cambridge Research Center.
† Permanent address: University of Houston.

KA10. Effect of Chemisorbed Hydrogen on the Magnetization of Cobalt. CARLOS R. ABELEDO* AND P. W. SELWOOD, *Northwestern University.*—We have investigated the effect of chemisorbed hydrogen on the saturation magnetization of small (about 100 A in diam) cobalt particles. These were supported on silica gel in the manner familiar in heterogeneous catalysis. Hydrogen lowers the saturation magnetization of the metal by about 0.4 Bohr magnetons per average hydrogen atom adsorbed. In the case of nickel[1] this decrease was about 0.7 Bohr magnetons per hydrogen atom.

* On leave of absence from Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina. Fellow of Texaco, Inc. and Consejo Nacional de Investigaciones (Argentina).
[1] R. E. Dietz and P. W. Selwood, J. Appl. Phys **30**, 101S (1959).

KA11. Cationic Distribution in Cobalt Spinels. JAMES T. RICHARDSON, *Humble Oil and Refining Company.*—The molecular field treatment of the cobalt spinel $Co_{x\,m}N_{(1-x\,m)}\times[Co_{(1-x)\,m}N_{2-(1-x)\,m}]O_4$ yields magnetic constants of the form $u^2=x\mu_A{}^2+(1-x)\mu_B{}^2$ and $\theta\mu^2=(A+Bx+Cx^2)m$, where μ_A and μ_B are the magnetic moments of Co^{2+} on tetrahedral and octahedral sites, respectively, and A, B, and C are related to the exchange integrals. Magnetic measurements were made on Co_2GeO_4 and $CoAl_2O_4$, whose cationic distributions were determined by x-ray diffraction, to establish values of μ_A and μ_B as 4.30β and 4.88β, respectively. These values are in agreement with those expected from crystal field considerations and were confirmed by measurements on Co_2TiO_4, whose distribution is known. The cation distribution parameter x was then determined from magnetic measurements of the series $Co_mZn_{2-m}TiO_4$ and $Co_mMg_{2-m}TiO_4$. It was found that Zn^{2+} replaces Co^{2+} exclusively on A sites, whereas Mg^{2+} substitutes equal on A and B sites, both as expected. The values of θ, μ, and x for all samples followed the expression given above, with the constants A, B, and C yielding estimates of the exchange integrals.

KA12. A Modified Spin-Wave Theory of Antiferromagnetism.* H. L. DAVIS AND JOHN C. GARRISON,† *Sandia Laboratory.*—A modified spin-wave theory is used in an attempt to better determine the low-lying excited states of the isotropic exchange Hamiltonian, $2J\,\Sigma\mathbf{S}_j\cdot\mathbf{S}_k$, where $J>0$, j and k run over separate sublattices, and the sum is confined to nearest neighbors. The spin operators are expressed in terms of Bose operators, a_j and b_k, in the usual fashion[1]: $S_j{}^+=(2S)^{\frac{1}{2}}f_s(n_j)a_j$, $S_k{}^+=(2S)^{\frac{1}{2}}b_k{}^+f_s(n_k)$, etc. After the Bose operators are Fourier transformed, another transformation of the form $a_\lambda=\alpha_\lambda\cosh\varphi_\lambda+\beta_\lambda{}^+\sinh\varphi_\lambda$, $b_\lambda=\alpha_\lambda{}^+\sinh\varphi_\lambda+\beta_\lambda\cosh\varphi_\lambda$ is used and the resulting Hamiltonian placed in normal order. In ordinary spin-wave theory, where $f_s(n)=1-(1/2S)n-\ldots$ and all terms of the Hamiltonian of higher order than $(1/2S)^0$ are discarded, one finds that $\tanh(2\varphi_\lambda)=-\gamma_\lambda$ will make the nondiagonal two-operator, terms of the Hamiltonian vanish. However, in our modification, by retaining higher order terms of $(1/2S)$, it is found that $\tanh(2\varphi_\lambda)=-\epsilon\gamma_\lambda$, with $0<\epsilon<1$, is necessary for the nondiagonal two-operator terms to vanish. Then the energy of excitation of our modified spin wave is proportional to $(1-\epsilon^2\gamma_\lambda{}^2)^{\frac{1}{2}}$ instead of $(1-\gamma_\lambda{}^2)^{\frac{1}{2}}$ as in ordinary spin-wave theory, i.e., we have an energy gap.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† Present address: Department of Physics, Purdue University.
[1] R. Kubo, Phys. Rev. **87**, 568 (1952).

FRIDAY AT 10:00

Auditorium 2 (C.M.)

(W. V. HOUSTON presiding)

Symposium in Theoretical Nuclear Physics

L1. A Schematic Theory of Nuclear Reactions. F. MEDINA, *Universidad Nacional Autónoma de México.* (30 min.)

L2. The Harmonic Oscillator and Supermultiplet Theory. M. MOSHINSKY, *Universidad Nacional Autónoma de México.* (30 min.)

L3. Use of Complex Variables in Elementary Particle Physics. R. J. EDEN, *University of Cambridge.* (30 min.)

L4. Mobility of an Electron in a Polar Crystal. R. P. FEYNMAN, *California Institute of Technology.* (30 min.)

FRIDAY AT 10:00

Auditorium 6 (C.M.)

(W. W. BUECHNER presiding)

Apparatus of Nuclear Physics

M1. Automatic Selection and Extraction of Radium Tubes and Needles. JOSÉ MIRELES MALPICA, *Instituto Politécnico Nacional, México.*—Each particular tube or needle containing radium salts is placed vertically in its own numbered lodgment, which is one of several holes drilled in numbered lead blocks. A rotating frame with two plates, each one containing 20 blocks, permits the placing in position of each one in front of the extraction door. The rotating frame is moved slowly by means of an electrical motor through belts and a worm gear. By means of a commutator and switches it is possible to stop automatically the motor, placing in front of one of the doors the block which contains the selected tube or needle. A lead stopper with a coupling device permits the extraction of the block and placing it where, by means of mirrors and special pincers, the radium needle is placed within its container for transportation to the operating room. Provision has been made for manual operation. The rotating frame is placed within an iron cylindrical enclosure, around which lead tubes and disks absorb radiations. An iron table supports the heavy absorbing mass and frame. Lead shields placed in front of the operator give additional protection.

M2. Error Sources and Precautions in the Determination of Low-Level Natural Radioactivity. A. MORENO M. AND H. O. NAVA J., *Institute of Physics, National University of Mexico.*—The installation of the low-activity laboratory of the Institute of Physics has given rise to considerable experience in the sources of errors and the necessary precautions in determining very low levels of activity. Dismountable Libby-type counters have been built with O-ring seals; only metals, Pyrex glass, and Teflon have been used, after studying the behavior of other plastics (Lucite, polyethylene, etc.) under vacuum. The stability of the counter is such that counting times of more than 2000 min are possible without significant alterations in the counting rate, since the losses due to air leaks are less than 0.15 μ in 10 min. The calibration in terms of ^{14}C content in recent wood samples is discussed.

M3. Design of Mutual Anticoincidence 4π Counters for Very Low Activities.—J. CALVILLO AND T. A. BRODY, *Institute of Physics, National University of Mexico.*—In 4π counters consisting of two halves of 2π geometry, a cosmic-ray particle has a higher probability of triggering both halves than do the particles emitted by the sample between the two halves. This is made use of in the mutual anticoincidence principle[1] (Alba, Brody, and Castro, 1959) to reduce the background count without reducing the sample count by eliminating electronically all pulses produced simultaneously in both halves. In the present paper different forms of the 2π counters are studied theoretically by Monte Carlo methods. Scattering inside the counter is not taken into account. The cosmic-ray intensities are considered to be distributed as a function of the zenithal distances θ as $\cos^p\theta$, where $p=0$, 1.8, 2, 2.2. Some of the designs have been built; the experimental data confirm the usefulness of the mutual anticoincidence principle and give an indication of the importance of scattering within the counter volume.

[1] F. Alba, T. A. Brody, and I. Castro, Rev. Mex. fis. 8, 117 (1959).

M4. Charge Collection in Semiconductor Particle Detectors.* G. L. MILLER, *Brookhaven National Laboratory,* AND W. M. GIBSON, *Bell Telephone Laboratories.*—Semiconductor particle detectors operate as do ion chambers by collection of charge liberated by an incident ionizing particle. However, the mechanism of charge collection is much more complicated than in the ion-chamber case, depending in detail on the properties of the semiconductor, the potential distribution in the device, and the ionization density along the initial track. Loss of charge can be attributed to recombination of holes and electrons in the dense plasma formed along the particle track or trapping of the moving carriers subsequent to their separation by the electric field. These effects can be distinguished by using particles of widely differing ionization density. Such investigations have been carried out for a variety of silicon diodes fabricated in different ways and covering a wide range of resistivities. A correlation between resistivity and collection efficiency and a reduction of collection efficiency for heavily ionizing particles has been observed. An analysis has been carried out for both trapping and recombination in homogeneous conductivity detectors and surface barrier junction detectors. Dependence of carrier loss on such factors as the resistivity, lifetime, and impurity con-

centration of the bulk silicon, the ionization density along the particle track and the applied bias have been investigated.

* This work was performed in part under the auspices of the U. S. Atomic Energy Commission.

M5. A Scintillation Spectrometer for High-Energy Beta Spectra.* J. G. CRAMER, B. J. FARMER, AND C. M. CLASS, *Rice University.*—A scintillation spectrometer using a large plastic phosphor has been developed to measure the beta spectra of a number of high energy (>5 Mev) short-lived emitters found in the light- and medium-weight nuclei. Spectra of a quality competitive with those measured in magnetic spectrometers have been obtained. The improvement in quality of these measurements over usual scintillation methods is achieved primarily by restricting the normally incident betas to a small axial region of the large cylindrical phosphor so as to insure almost total absorption of the beta energy. The energy scale of the spectrometer is calibrated with standard beta spectra and the Compton edges of γ rays. End-point energies can be assigned to an accuracy of 1–2%. The spectra are recorded with a multichannel analyzer. Advantage is taken of the the complement mode of the analyzer to subtract background while the betas are stopped in a polyethylene screen. Sample spectra provided by the decays of Li^8, B^8, N^{13}, F^{20}, and Al^{28} will be presented and compared with those obtained with magnetic spectrometers. Distorting effects due to bremstrahlung and backscattering will be discussed.

* Supported in part by the U. S. Atomic Energy Commission.

M6. Accuracy of Bubble Location in a Bubble Chamber.* ROBERT W. WILLIAMS, *University of Washington.*—Measurements of bubble coordinates have been made on a set of pictures which should have a minimum amount of extraneous error in bubble location. These films, kindly supplied by Dr. I. A. Pless, present tracks of 460-Mev protons in a very small, all-glass negative-pressure isopentane chamber,[1] photographed at essentially one-to-one magnification. The time between particle passage and light flash was about 2 μsec. The influence of film grain, turbulence, and differential refractivity were therefore very small, and an inherent bubble location error of even a few microns should reveal itself. Consecutive bubbles (average density 33 per centimeter) were measured at 100 × with a filar-eyepiece microscope. The reproducibility of setting on the center of the diffraction images was 4.2 μ, corresponding to 4.6 μ in space. The rms deviation of the bubble positions, from second differences, was 4.7 μ, essentially the same. We conclude that the centers of the bubbles correspond to the true position of the particle trajectory to better than 4 μ.

* Supported in part by the Office of Naval Research and the National Science Foundation.
[1] I. A. Pless, Phys. Rev. **104**, 205 (1956).

M7. An Experimental Investigation of the Theory of the Bubble Chamber.* LEONARD O. ROELLIG, ALLAN G. BECKER, STEPHEN S. WILSON, *Wayne State University.*—The effect of ionizing radiation on superheated ethyl ether has been studied. Two experimental methods were used. The first method consisted of slowly lowering the pressure on the liquid, and observing the pressure at which boiling occurred. The boiling pressure was measured as a function of the temperature of the liquid, the type of radiation, and the strength of the radiation bombarding the liquid. The second method consisted of rapidly lowering the pressure to a fixed pressure and then measuring the time elapsed before boiling occurred. The waiting time was measured as a function of the temperature, pressure, and type and strength of the bombarding ionizing radiation. The types of ionizing radiation were 1–10-Mev neutrons, 24-kev neutrons, and 30 kev to 1.3-Mev gamma rays. These studies showed that the destruction of the superheated state depends upon the energy of the neutrons, but not upon the energy of the photo and Compton electrons produced in the liquid. Instead, the destruction of the superheated state depended critically upon the number of electrons which stopped in the liquid. Data will be given to show how these experimental methods can be used to study fluctuation phenomena in superheated liquids.

* Supported in part by a grant from the National Science Foundation.

M8. Information Content of Particle Tracks.* WALTER H. BARKAS, *Lawrence Radiation Laboratory, Berkeley.*—Measurable features of emulsion, bubble-chamber, or cloud-chamber tracks inclined with arbitrary dip are operationally defined. The information content of such tracks is analyzed with respect to the prime track variable g and to the particle velocity on which g depends. The theory of the projected linear structure of such tracks and previously derived connections between the true value of g and the measurable track features are reviewed.[1] A new and independent estimate of g based on the mean blob length is introduced. The two independent quantities, mean gap length and mean blob length, each yield measurements of g. These can be combined linearly to obtain an optimum estimate of g. It is argued that in a practical sense this exhausts the information content of the track.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] Walter H. Barkas, University of California Radiation Laboratory, Rept. No. UCRL-9181.

M9. Precision Magnetic Field Measurements. H. A. HOWE, T. DAHLSTROM, E. SMITH, AND W. MALLET, *U. S. Naval Radiological Defense Laboratory.*—Accelerators employing magnetic fields require accurate measurement of these fields. Employment of the Hall effect in the recently developed semiconductors, indium-arsenide and indium-antimonide, meets these strict magnetic field measurement requirements. The semiconductors, produced and encapsuled by Siemens Corporation, have the following approximate characteristics depending upon the size and type of semiconductor. At the rated current through the semiconductor, the Hall voltage is about 0.1 v at 10 kgauss. The temperature coefficient is small (~0.07%/°C) but varies as much as 50% for different magnetic fields. The long time stability is good with a measured variation over a year of less than 1 part in 10 000. Semiconductors with effective dimensions from 1 to 12 mm are available. With a special value of electrical load on the output terminals linearity better than 0.5% is obtainable from 0 to 10 kgauss. A detailed description of the temperature coefficient of the Hall potential, the internal resistance of the semiconductor, will be presented along with a description of a temperature compensating network which yields a magnetic-field-measuring probe with a temperature coefficient of less than 0.01%/°C over a magnetic field range from 6 to 25 kgauss. The importance of thermal time constants of the semiconductor will be discussed and some measurement results presented.

M10. Fields in Cavity-Excited Accelerators.* E. G. CRISTAL AND J. VAN BLADEL, *Midwestern Universities Research Association and University of Wisconsin* (introduced by B. Waldman).—Field configuration and resonant frequency are determined for the lowest azimuthally independent mode of a coaxial cavity surrounding a circular tube. Several values of the width of the coupling gap are considered, and the central problem consists in determining the tangential electric field $\bar{E}_t$ in that gap. It was found that the fields near the axis of the accelerator are quite insensitive to the actual profile of $\bar{E}_t$, and that satisfactory results are obtained by assuming $\bar{E}_t$ to be constant. The problem is repeated for a parallel-plane configuration,

with the purpose of investigating the influence of the flattening of the cavity. Computations show that the two configurations yield fairly similar results.

* Supported by the U. S. Atomic Energy Commission.

M11. Photon Noise. S. J. KLAPMAN, *Hughes Aircraft Company.*—The technology of various photon detectors has advanced to such a state that fluctuations in the number of photons in a beam of photons incident on a detector have become important. It is true that the differences discussed in this paper are negligible for a practical case, but the driving motive is one of consistency. Jones[1] has derived an expression for photon noise making use of a theorem derived by Callen and Welton.[2] In order to study the details of photon arrival at a detector Jones also employed "shot noise" theory in a second derivation, and arrives at a result inconsistent with the result based on the Callen and Welton theorem. The treatment presented here uses "shot noise" theory and derives the photon noise consistent with Callen and Welton, by considering the transition probabilities within the detector.

[1] R. C. Jones, *Advances in Electronics. V* (Academic Press Inc., New York, 1953), pp. 18–23.
[2] H. B. Callen and T. A. Welton, Phys. Rev. **83**, 34 (1951).

M12. Multichannel Uniform-Field Beta-Ray Spectrometer. J. A. JUNGERMAN, N. F. PEEK, AND S. M. SMITH, *University of California, Davis.*—A solenoidal beta-ray spectrometer has been designed which utilizes five beta-ray channels. Transmission of the spectrometer is 13% at a resolution of 0.5%. If positrons are counted in coincidence with electrons, using the statistical method employed by Alburger,[1] the instrument may also be used for detection of pairs. For isotropic emission the pair transmission efficiency is improved by a factor of 40 as compared with a single-channel instrument with a detector of 40 as compared with a single-channel instrument with a detector split into two azimuthal parts.

[1] D. E. Alburger, Rev. Sci. Instr. **27**, 991 (1956).

FRIDAY AT 10:00

Auditorium 5 (C.M.)

(LEWIS AGNEW presiding)

Electron Physics I

MA1. Thermionic Probe Emission in Alkali-Seeded Flames. W. S. EMMERICH, *Westinghouse Research Laboratories.*—Probe measurements were carried out in the combustion products of hydrogen and oxygen, seeded with potassium carbonate. Single probes in form of tungsten cylinders were inserted into the flame with their axes at right angles to the flow of the gas. Flame and probe temperatures were determined by sodium-line reversal technique and optical pyrometry, respectively. Temperature of the probe surface was varied between 1500° and 2200°K by the application of conduction cooling. Thermionic saturation was observed corresponding to effective work functions on the order of 3 v which is below that of the probe material, when pure. This effect is attributed to the presence of the alkali metal in the flame, and possibly a partial coverage of the probe surface with potassium. As the applied voltage is raised, the probe current increases sharply and under some conditions, cathode spots are visible on the probe surface.

MA2. Correlations between Cathode-Ejected Material and the Characteristics of an Abnormal Glow Discharge. ERIC KAY, *IBM Research Laboratory, San Jose* (introduced by L. H. Thomas).—Physical and chemical properties of thin films prepared in a parallel planar electrode apparatus operated in the abnormal glow discharge region are greatly influenced by the relative position of the collecting substrate with respect to the characteristic zones of the discharge. Correlations of mass distribution of sputtered material with structural properties of thin films determined by electron microscopy and diffraction will be presented. Symmetrical radial distribution of condensed material was obtained only when substrates were held well within the field-free negative glow region where shadow effects normally encountered in the Crookes dark space due to ion and electron-ray properties are absent. Apparatus walls, whether conducting or nonconducting, held close to cathode periphery to be within a mean free path of electrons and neutral gas atoms, as a means of containing the discharge, produces distortions in radial distribution of the condensed material. Distribution of sputtered material perpendicular to the cathode plane and accompanying structural properties will be presented. An effective sputtering ratio for Al of 0.77 at a glow discharge pressure of 6×10^{-2} mm Hg for an argon ion energy of 2000 ev suggests that back diffusion of sputtered material to the cathode is not as serious as anticipated.

MA3. Kinetic-Energy Distribution of Ionic Fragments from Some Hydrocarbons under Electron Impact.* J. E. MONAHAN AND H. E. STANTON, *Argonne National Laboratory.*—A modified form of double-focusing mass spectrometer has been used to determine the distribution in kinetic energy of the ionic fragments formed from hydrocarbon molecules under electronic impact. The distributions obtained generally have been fitted by a modified Maxwell distribution from which a "temperature" could be obtained. The analyses for hydrocarbons nearly always led to "temperatures" corresponding to $kT<0.5$ ev. As pointed out by Taubert,[1] the value of kT frequently increased with decreasing mass of the fragments and with progressive decrease in the number of attached hydrogen atoms. Exceptions to this method of theoretical treatment are found for O^+ from CO, emthyl ions from the saturated aliphatics and benzene, and others whose kinetic-energy distributions exhibit high-energy components.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] R. Taubert, in *Advances in Mass Spectrometry*, edited by J. D. Waldron (Pergamon Press, New York, 1959), p. 489.

MA4. Evidence for a Bound Excited State of C^-.† L. M. BRANSCOMB AND M. SEMAN, *National Bureau of Standards.*—Very little is known about the electronic structure of atomic negative ions. Semiempirical theoretical arguments[1] lead to the expectation that electronically excited configurations of light atomic ions would not be stable. Of those light ions containing several terms of the ground-state configuration (B^-, C^-, N^-, Al^-, Si^-, and P^-) it was anticipated that Si^{-2} ^2D and $N^{-1}D$ might be metastable, the former decaying to $Si^{-4}S$ and the latter to the continuum. The negative atomic carbon

ion was expected to have only one bound state: the ^4S ground state. Of the ions, only C^- has been studied spectroscopically.[2] We find an infrared continuum beyond the threshold for absorption from the ground state, previously identified as the ^4S state with an electron affinity in the neighborhood of 1.18 ev. While the shape of this continuum cannot be unequivocally determined from our data, and we cannot determine the detachment cross section (because of ignorance of the excited-state population), we feel the evidence is convincing that the absorption arises from a metastable excited state of C^-, presumably ^2D.

† Supported in part by the Office of Naval Research.
[1] D. R. Bates and B. L. Moiseiwitsch, Proc. Phys. Soc. (London) **A68**, 540 (1955).
[2] M. Seman, M. A. Fineman, and L. M. Branscomb, Bull. Am. Phys. Soc. **6**, 29 (1961).

MA5. Electron Impact Ionization of Atomic Hydrogen and Atomic Oxygen.* ERHARD W. ROTHE, LAWRENCE L. MARINO, R. H. NEYNABER, AND S. M. TRUJILLO, *Convair, San Diego.*—The total cross sections for the ionization of atomic oxygen and atomic hydrogen have been measured by a modulated molecular-beam technique. The basic measurement compared the number of ions formed in a region defined by the intersection of an electron beam and a modulated molecular beam with the number formed when the neutral beam is partially dissociated. All ions are collected, including those energetic ones formed in dissociative ionization of molecular oxygen. A radio frequency discharge dissociated about 30% of the molecules, in both hydrogen and oxygen. The degree of dissociation was measured with a mass spectrometer. From the data, the ratio of the atomic to the molecular ionization cross sections are obtained. The absolute atomic values are calculated by multiplying these ratios by the molecular ionization cross sections of Tate and Smith.[1] The results are compared with theoretical estimates and previous experimental determinations.

* Supported in part by the Advanced Research Projects Agency (Project Defender) through the Army Rocket and Guided Missile Agency.
[1] J. Tate and P. Smith, Phys. Rev. **39**, 270 (1932).

MA6. Breakdown Characteristics of a Transfer Discharge. LORIN K. HANSEN AND KENNETH R. MACKENZIE, *University of California, Los Angeles.*—An electrical breakdown mechanism has been studied which is not characterized by electron emission from wall or electrode surfaces, and can be excited at medium frequencies, low pressures and relatively low voltages. Ionization for the discharge is produced by electrons oscillating along a magnetic field and within a coaxial system of electrodes. Energy is fed into the discharge at rf frequencies by periodic transfer of the oscillating electrons between two anodes. The name "transfer discharge" has been coined for discharges using this basic mechanism. Various parameters for the discharge at breakdown have been related and will be discussed.

* Supported in part by the joint program of the U. S. Atomic Energy Commission and the Office of Naval Research.

MA7. Steady-State Characteristics of a Transfer Discharge.* KENNETH R. MACKENZIE AND LORIN K. HANSEN, *University of California, Los Angeles.*—Characteristics of a transfer discharge in the steady-state (see preceeding abstract) will be discussed. Observations have been made between pressures of 4×10^{-6} mm Hg to 0.2 mm Hg. Electrode current dependence is related to such parameters as bias voltages, rf voltage and frequency, magnetic field strength, and geometry. These relationships will be discussed in terms of the "transfer" mechanism. Minimum bias voltages range from 50 to 200 v and rf voltages range from 10 to 50 v. Frequencies have been used ranging from 500 kc to 10 Mc. Magnetic fields employed have been of the order of a few hundred gauss. Characteristics of the discharge suggest applications where wall effects and possible gas contaminations are undesirable.

* Supported in part by the joint program of the U. S. Atomic Energy Commission and the Office of Naval Research.

MA8. Microwave Breakdown in Air and Nitrogen.* A. D. MACDONALD AND D. U. GASKELL, *General Telephone and Electronic Laboratories.*—Electric fields required to initiate breakdown in air and in nitrogen at a frequency of 9.4 kMc have been measured. Measurements have been made for pressures varying from 50 μ to 150 mm Hg, in several resonant cavities. The cylindrical cavities are of different sizes so that the characteristic diffusion length varies from approximately 0.05 to 0.5 cm for single mode cavities and to higher values for multimode cavities. This variation of characteristic diffusion length enables one to study the relative effects of attachment and diffusion as removal processes for electrons in air. The measurements are compared with data at 3 kMc through calculation of effective fields. The results show that the use of an effective electric field, defined in the usual manner, is not a valid procedure for predicting breakdown at one frequency from breakdown data obtained at a second frequency.

* This work was supported by the Rome Air Development Center of the U. S. Air Force.

MA9. (Abstract withdrawn.)

MA10. Motion of Charged Particles in an Electrodeless Ring Discharge.* MARY F. ROMIG, *The Rand Corporation.*—The collision-free motion of charged particles is found for the case of an electrodeless ring discharge at breakdown. This radio-frequency field configuration consists of a spatially constant axial magnetic field and an azimuthal electric field which varies linearly with distance from the discharge tube axis. An analytic solution is obtained for the equations of motion. It is found that stable (time-bounded) solutions exist for certain values of the ratio of cyclotron frequency to applied field frequency. The motion is contained within the discharge tube, for arbitrary initial position, only for those particles which start from rest. Protons and heavier particles experience little motion in this environment.

* This work was performed while the author was associated with the Convair Division, General Dynamics Corporation, San Diego, California.

MA11. Nonlinear Propagation of Strong Electromagnetic Waves through Weakly Ionized Water Vapor. PAUL MOLMUD, *Space Technology Laboratories.*—A theoretical treatment of the nonlinear propagation of strong electromagnetic waves

through weakly ionized water vapor is presented. When the parameters of propagation are held within certain constraints, analytical solutions describing the propagation of plane waves through a uniform medium may be obtained. These solutions are applied to the problem of propagation through rocket exhaust gases. A novel method is described for altering the attenuation experienced by a signal sent from the ground, through the exhaust gases, to a rocket-propelled vehicle. This is accomplished by broadcasting a powerful "sacrificial" wave from the vehicle through the exhaust thus altering its electrical characteristics.

MA12. Self-Generated Potential Gradients in the Penning Discharge. F. SALZ, R. G. MEYERAND, JR., E. C. LARY, AND A. P. WALCH, *United Aircraft Research Laboratories.*—The existence of potential gradients in a nonthermal plasma is investigated. It is found that potential gradients may exist in a plasma over dimensions that are large compared to the Debye length provided that the ion and electron velocity distributions are consistent with the conditions of charge neutrality. The potentials within the plasma may be calculated without the direct use of Poisson's equation by equating the densities of ions and electrons through an equation for the flux-velocity quotient where both the flux and velocity distribution are determined by the potential. A model of the Penning discharge based on the presence of such self-generated and self-maintained potential gradients is postulated. The predicted potentials are compared to those measured experimentally by means of both conventional and emitting Langmuir probes. The operation of the Penning discharge in terms of the potential gradients and the effects of neutral gas pressure, cathode current, magnetic field, and applied voltage are discussed.

MA13. Quenching of the Pink Nitrogen Afterglow by an ac Electric Field. ROBERT A. YOUNG, *Stanford Research Institute.*—The short-duration pink afterglow of nitrogen recently investigated by Beale and Brodia[1] is affected either by an extremely weak discharge or, more probably, by an ac electric field. A Tesla discharge between foil electrodes attached externally to a 20-mm-diam Pyrex tube through which the short duration afterglow streams greatly reduces the intensity of the N_2 1st positive bands and the N_2^+ 1st negative bands several tube diameters on either side of the electrodes. Measurements of the quenching of radiation in the vacuum ultraviolet region will also be reported. The implications of these observations on the excitation mechanism of the short duration afterglow will be discussed.

[1] G. Beale, Jr., and H. Broida, J. Chem. Phys. 31, 1030 (1959).

MA14. Observations of the ac Phenomenon in Cesium Diodes.* HUGH L. GARVIN, *General Atomic.*†—This paper reports the findings of a study made on the oscillatory characteristics of a cesium-vapor diode. Observations were made on the dependence of the cell output oscillations upon the operating parameters including cathode temperature, cesium vapor pressure, terminal voltage, and the cathode-to-anode spacing. The time interval between the pulses in the output current were found to be strongly dependent on terminal voltage when the anode was negative with respect to the cathode. When the anode was positive, however, the pulse interval was insensitive to voltage changes. The relationship of pulse interval to interelectrode spacing confirms the results of the experimental observations made by Gottlieb and Zollweg[1] for certain operating conditions.

* This work supported in part by the Rocky Mountain-Pacific Nuclear Research Group and by the San Diego Gas and Electric Company.
† John J. Hopkins Laboratory, General Atomic Division of General Dynamics Corporation, San Diego, California.
[1] M. Gottlieb and R. J. Zollweg, Bull. Am. Phys. Soc. 5, 383 (1960).

FRIDAY AT 14:30

Auditorium 5 (C.M.)

(L. M. BRANSCOMB presiding)

Electron Physics II

N1. Low-Temperature Thermionic Energy Converter. W. BERNSTEIN, *Hughes Research Laboratories.*—In order to achieve high output currents (10 amp/cm²) in thermionic energy converters, the electron space charge must be neutralized. Consideration of ionization efficiency shows that the usual plasma production method through contact ionization of cesium vapor at the hot cathode, is insufficient to produce the required plasma density at the desirable operating temperature of 1500°K. A simple method for the production of a plasma of the required density in the interelectrode space will be given. It will be shown that the power required to maintain the plasma represents about 5% of the output power of the device. This method of plasma generation can permit relatively low temperature (1500°K) operation at about 25% conversion efficiency at 10 w/cm² output power. The problems of producing satisfactory cathodes and 1.0 ev work function anodes will be discussed. Preliminary experimental results which show that adequate space-charge neutralization can be attained will be given.

N2. Enhanced Emission Currents from Tantalum and Molybdenum in Cesium Vapor. TOMAS E. FIRLE, *General Atomic.**—Experimental coaxial diodes were constructed in which both electrodes were operated at approximately the same temperature. Tantalum and molybdenum were used as emitters. Measurements of the static voltage-current characteristics were made for the vacuum case and with cesium vapor up to a vapor pressure corresponding to 0.2 mm Hg. Data showing emission currents will be presented for a range of electrode temperatures from 1050° to 2200°K. Plots of emission current against reciprocal temperature with cesium vapor pressure as parameter result in "S" curves qualitatively similar to the Langmuir type reported for tungsten.[1,2] The emitter work function changes as the cesium surface coverage decreases with increasing temperature; an enhanced thermionic emission results, leading to a maximum typically around 1350°K. The observed maximum-to-minimum current ratio is about 5:1.

* John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic Division of General Dynamics Corporation, San Diego, California.
[1] J. B. Taylor and I. Langmuir, Phys. Rev. 44, 423 (1933).
[2] V. C. Wilson, J. Appl. Phys. 30, 475 (1959).

N3. Thermionic Emission of Refractory Metals in Cesium Vapors.* JOHN M. HOUSTON, *General Electric Research Laboratory.*—The thermionic emission of six polycrystalline refractory metals was measured in Cs vapor using the "plasma

anode" technique described by Marchuk.[1] In this technique a small loop of wire is immersed in a Cs plasma in a conventional gas discharge tube, and run negative with respect to plasma potential. The incoming ion current to the loop neutralizes the outgoing thermionic emission, and allows large emission densities to be measured before encountering electron space charge. To date measurements have been made only at low Cs pressures. At a Cs reservoir temperature of 100°C and with all six probes in the same plasma under identical conditions, the peak of the emission vs emitter temperature curve was found to occur at approximately the following emission current densities in amp/cm²: W, 7×10^{-3} (agrees well with Taylor-Langmuir[2]); Re, 5×10^{-3}; Mo, 4×10^{-3}; 50% Mo-W alloy, 2×10^{-3}; Ta, 1×10^{-3}; Nb, 1×10^{-4}.

* This work performed under U. S. Force sponsorship.
[1] P. M. Marchuk, Trudy Inst. Fiz. Akad Nauk Uk. S. S. R. **7**, 17 (1956).
[2] J. B. Taylor and I. Langmuir, Phys. Rev. **44**, 423 (1933).

N4. Operating Characteristics of a Cesium Diode Utilizing Fission Heating of the Emitter.* W. Reichelt, G. Grover, E. Salmi, and W. Schafer, *Los Alamos Scientific Laboratory*, Short circuit currents, open circuit voltages, power curves, and general operating characteristics are given for a series of cesium plasma diode experiments which utilize fission heat to obtain high emitter temperatures (to 2200°K). These experiments were performed in the Omega West Reactor facility at the Los Alamos Scientific Laboratory. The experimental configuration of the plasma cell was cylindrical, the emitter a cylinder of $(UC)_{0.3}(ZrC)_{0.7}$ with an area of 4.7 cm² and the emitter collector spacing 0.040 in. Maximum short circuit current, open circuit voltage, and power output have been 130 amp, 4.2 v, and 85 w, respectively. Where operating pin temperature was measured, the data correspond favorably with the electrically heated plasma cell data.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

N5. Scattering of Electrons by Cesium Atoms.* R. J. Zollweg and Milton Gottlieb, *Westinghouse Research Laboratories*.—Cross sections for scattering of electrons by Cs atoms have been obtained from measurements of the dependence of electron mobility on magnetic field strength in transverse dc electric and magnetic fields. In accordance with theory,[1] the ratios of the saturation cell currents to measured cell currents were found to be linear with the square of the magnetic field strengths, with the slopes yielding the values of the collision frequencies and scattering cross sections. Measurements were made over a range of cesium pressures up to 10 mm Hg and as a function of cathode-anode potential. A range of saturation emission currents was used to guard against errors associated with space charge effects. The results, appropriate for conditions likely to be encountered in cesium plasma thermionic converters, are compared with the older data in the literature. Difficulties and limitations of the technique will be discussed.

* Supported in part by the U. S. Air Force Electronic Technology Laboratory, WADD.
[1] W. P. Allis, *Handbuch de Physik*, edited by S. Flügge (Springer-Verlag, Berlin, Germany, 1956), Vol. 21, p. 383.

N6. Observations of Thin-Film Sputtering at Low Energies with the Electron Microscope.* H. Poppa† and D. B. Medved,‡ *General Dynamics Corporation*.—An auxiliary apparatus for an Hitachi HU-10 electron microscope has been developed which permits the measurement of the thickness of thin films before and after exposure to bombardment by noble gas ions without removing the specimen from the microscope vacuum. Changes in thickness of the film are determined by electron absorption measurements. The electron absorption of the film as a function of thickness was calibrated using Tolansky multiple-beam interferometry. The ion source attached to the microscope specimen chanber is a low voltage 5-μ dc discharge. The range of ion energies initially investigated was 50 to 150 ev with exposure times to the ion beam being on the order of 30 sec to 4 min for measurable sputtering to occur. The influence of exposure time, current density, and target film thickness on the sputtering yields was investigated. Sputtering yield values for Ar^+ on Ag films varied from 2×10^{-2} at 50 ev to 4×10^{-1} at 150 ev. These values are lower than those obtained by Wehner for sputtering of bulk polycrystalline silver by Ar^+ in the same energy range.[1] Several explanations for this will be discussed.

* Supported in part by U. S. Air Force contract.
† Convair Astronautics.
‡ Convair Physics Section.
[1] G. K. Wehner, Rept. 1902, Nonr-1589(15) (May 31, 1959).

N7. Low Energy Sputtering Studies.* D. McKeown, A. Y. Cabezas, and H. E. Adelson, *Convair Astronautics*.†—A program has been initiated to study the sputtering of various materials in ion beams of noble gases between 0 and 1000 ev by the crystal oscillator method.[1] The materials to be studied are deposited as thin films approximately 3000 A thick on optically polished quartz crystals. The plated crystals are then bombarded in the beam. 20 Mc crystals are used and sputtering of 2×10^{-10} g of plating can be measured by the increase in the resonance frequency of the crystal. Data of the initial results, the sputtering of Al and Au surfaces, will be presented.

* Research supported by the Office of Naval Research.
† Space Physics Laboratory, Convair Astronautics, Division of General Dynamics Corporation, San Diego, California.
[1] D. McKeown, Rev. Sci. Instr. **32**, 133 (1961).

N8. Range of Kilovolt Electrons in Solids. H. Kanter and E. J. Sternglass, *Westinghouse Research Laboratories*.—The maximum range of electrons, as distinguished from the extrapolated or practical range, has been measured in Al, Al_2O_3, Ni, Ag, and Au for electron energies between 1.0 and 10.0 kev. The technique utilized involves the detection of the onset of penetration through freely supported evaporated films by observation of the current collected in a 2π geometry. The range defined in this manner may be compared with the predictions of stopping theory, with little influence of scattering processes. The results show no significance Z dependence of the exponent in the range-energy relation, in agreement with results at higher energies. Some indications exist for an increasing value of the absolute range with increasing Z when expressed in mg/cm², in accordance with the theoretically predicted decrease in stopping power for heavier elements. The results are compared with recent measurements using the onset and decline of luminosity in a phosphor layer to define the range. Although reasonable agreement exists with the data on metals, this is not found to be the case for the ranges in phosphors. It will be shown that the differences in results may be traced to the nature of the detecting techniques employed, which in some cases are sensitive to the total energy rather than the number of particles reaching a given depth.

N9. On the Acceptance of Slow Electrons at the Surface of Al_2O_3 and the Accurate Determination of the Insulator Surface Potential by the Beam Electrons.* H. Heil, RCA *Laboratories, Princeton*.—An electron energy spectrograph of the retarding field type primarily designed to analyze energy distributions in beams is described. Use of a fine mesh as counterfield electrode and subsequent acceleration of the electrons to a collector eliminates the usual inaccuracies in the spectral intensities arising from incomplete acceptance or secondary emission of the electrons. Parallelity of the trajectories at the selector mesh to less than 0.030 ev of radial energy permits good energy resolution and investigations with very slow electrons. The instrument was found useful in

studying thin insulator films borne by the mesh. With a beam of 0.2 ev half-maximum width, electron acceptance curves down to energies almost as low as the instrument resolution can be obtained by recording both the mesh and collector current. A rise of acceptance to about 100% for low energy at Al_2O_3 and MgO was observed. By using the collector current displayed on an x-y recorder as monitor, one can detect insulator surface potential changes as small as 2 mv. This procedure permits determination of what part of the accepted electron current contributes to charging of the insulator surface and what part is conducted through the thin Al_2O_3 film.

* Supported by the Wright Air Development Center, Electronics Components Laboratory.

N10. Cleavage of Crystals in High Vacua. N. R. WHETTEN AND T. A. VANDERSLICE, *General Electric Research Laboratory.*—Single crystals of alkali halides have been cleaved in vacua of 10^{-9} mm or lower to produce clean surfaces. A small burst of gas has been observed to be given off as the crystal is cleaved. The gas has been analyzed using a bakeable, ultrasensitive mass spectrometer[1] capable of detecting partial pressures of 10^{-16} mm under favorable conditions. The gases observed have been primarily CO, CO_2, and H_2O. The amount of gas released during cleavage has been found to vary from one molecule for every 10^7 surface atoms exposed to one for every 10^3.

[1] T. A. Vanderslice and W. Davis, Trans. Am. Vacuum Soc. Meeting, October, 1960.

N11. On the Current Distribution in Electrically Exploded Foils.* M. L. MERRITT, *Sandia Laboratory.*—Copper foils subjected to the high-current discharge of a capacitor bank show, while still solid, a longitudinal structure suggestive of shear currents and mechanical pinch effects.[1] In fact, samples so distorted have been recovered by cutting off the discharge at that time. Assuming a very thin foil, the lateral current distribution under an imposed current $I(t)$ is

$$j(x,t)=\frac{1}{2a}[I(t)-I(0^+)]+\sum_{n=1}^{\infty} J_0(n\pi)\cos\frac{n\pi x}{a}\int_0^t \exp\left[\frac{-n^2\pi^2(t-u)}{\mu\sigma a^2}\right]I'(u)du.$$

Magnetic fields have been measured about such foils; currents inferred from them are compared with those predicted as above. Best fits come using conductivities lower than for cold copper, indicating heating and possibly other nonlinear effects.

* This work performed under the auspices of the U. S. Atomic Energy Commission.

[1] E. C. Cnare, J. Appl. Phys. 32, 1043 (1961).

N12. Method of Testing Directional Effects of the Intrinsic Electric Breakdown of Cubic Crystals in Uniform Fields. ALONSO FERNÁNDEZ, *The Institute of Physics, University of Mexico.*—The experimental setup used permits applying a field of a known and equal intensity to the (100), (110), and (111) directions in a single test. The direction of maximum electric field makes equal angles with the three main directions. The tests were performed on recessed plates with electrodes such that in the region of its maximum intensity the electric field was nearly uniform. Precautions were taken in the preparation of the specimens and the procedure of the testing to insure intrinsic breakdown. The result of the tests carried out on NaCl specimens at a temperature ranging from $-38°$ to $-54°$C are not in agreement with the path direction predicted by the theory of Offenbaker and Callen but agrees with other experimental results.

N13. Electron Transport at High Temperatures in the Presence of Impurities. J. L. LEBOWTIZ,* *Yeshiva University* AND H. L. FRISCH, *Bell Telephone Laboratories.*—The electrical transport properties of a solid at high temperatures is often determined primarily by the scattering of electrons by phonons and impurities. We investigate this problem for the case when the electrons are described by a classical distribution function in position and velocity $f(r,v)$. This function satisfies a space dependent equation in which the interaction with the impurities is treated as part of the Hamiltonian and the phonon scattering is described by a Boltzmann collision term. This equation is solved formally in the presence of a weak external electric field, and it is shown rigorously, for a wide class of collision terms, that the change in conductivity due to the presence of impurities is always negative. We also find explicitly solutions for the distribution function for some one-dimensional models. We find that in some situations (e.g., when the force is not continuous) the change in the distribution function due to the introduction of impurities contains terms which are not expandable as a power series in the lattice relaxation time.

* Supported by the U. S. Air Force Office of Scientific Research.

FRIDAY AT 14:30

Auditorium 3 (C.M.)

(S. H. NEDDERMEYER presiding)

Invited Paper

P1. Los Neutrones de la Radiación Cosmica y los Efectos Solar-Terrestres. SERGE A. KORFF, *New York University.* (30 min.)

Cosmic Rays and Space

P2. Size Spectrum of Cosmic-Ray Air Showers.* JOHN LINSLEY AND LIVIO SCARSI,† *Massachusetts Institute of Technology.*—A scintillation counter array with sensitive area 2 km² has been used at the M.I.T. Volcano Ranch Station (elevation 5800 ft) to measure the absolute differential intensity of air showers as a function of shower size and zenith angle. The results indicate that the energy spectrum of primary cosmic rays extends with no increase in slope from the energy region covered by previous experiments to nearly 10^{19} ev. Showers in the observed size range (mostly with $N>10^8$) are shown to be near maximum longitudinal development at the level of the Station.

* Supported by the National Science Foundation.
† Now at the University of Milan, Milan, Italy.

P3. Interesting Air Shower of about 70° Zenith Angle.* P. J. Eccles and John Linsley, *Massachusetts Institute of Technology.*—This shower was recorded after the array for the preceeding paper had been increased by a factor of 4 simply by increasing linear dimensions. It fired 12 out of the 19 3.2 sq m detectors. It appears like a normal shower to about 500 m from the core. Between this and the limit of observation (2500 m) it is much flatter than normal. Three "adjacent" detectors about 2300 m from the core demand this flatter distribution. These are time and directionally coherent with the other nine detectors. Photodisintegration of this primary into two or more fragments by Doppler-shifted solar photons was unlikely closer than 1 astronomical unit away. Hence the three detectors recorded secondaries from interactions in our atmosphere. A tentative explanation is that the shower was very old and at maximum was very large. Particles observed are mostly muons originating perhaps 20 km away, at which distance the nucleon cascade looks like a point source. The average angular distribution of muons from the cascade is thus available in a way which would not be possible with a smaller experimental array.

* Supported by the National Science Foundation.

P4. Radiation Belts and the Stormer's Inner Allowed Regions. Ruth Gall, *Instituto de Goefísica of the National University of Mexico and Instituto Nacional de la Investigación Científica.*—The role of the inner allowed regions as trapping zones for the high-intensity belts' particles is studied. The gammas corresponding to the allowed regions are calculated on the basis of the Van Allen energy spectrum of the trapped protons and electrons. Large values of gammas are so obtained. The conditions imposed by high gammas on the injection mechanism are discussed. The lines of force, their relation to the allowed regions and the shrinkage of the region into the line of force for large gammas are studied. Several types of trapped orbits are shown. The relations between the radius of curvature and the half-width of the allowed regions for small and large values of gammas are deduced.

P5. Protons in the Lower Radiation Belt.* Stanley C. Freden and R. Stephen White, *Lawrence Radiation Laboratory (Livermore).*—Two nuclear emulsion stacks were exposed to the lower radiation belt aboard an Atlas missile which was launched from Cape Canaveral on October 13, 1960. The nose cone reached an altitude of about 1200 km and was recovered near Ascension Island. The proton energy distribution and flux between 15 and 700 Mev, integrated over the trajectory of the vehicle, were obtained in one stack. Energy distributions above 70 Mev were obtained at six different altitudes in the second stack using a programmed device which rotated one set of emulsions over another in six discrete steps. The energy distribution measured in the fixed stack agrees with those obtained from our previous flights. From 40 to 300 Mev the data also agree well with the predicted spectrum[1] but tend to fall slightly below it at higher energies. Below 40 Mev the data bend away from the calculated curve to give a peak at 30 Mev. Results will be presented concerning the variation of the proton energy distribution with altitude.

* Work done under the auspices of the U. S. Energy Commission.
[1] S. C. Freden and R. S. White, J. Geophys. Research **65**, 1377 (1960).

P6. Flux and Spectrum of Charged Particles in the Lower Van Allen Belt.* Alice H. Armstrong, *Los Alamos Scientific Laboratory,* and Harry H. Heckman, *Lawrence Radiation Laboratory.*—The differential energy spectrum of protons in the lower Van Allen radiation belt has been measured with emulsions looking directly out the rear of a recoverable nose cone on an Atlas missile, which attained a maximum altitude of nearly 1200 km in the region of the geomagnetic equator. Detailed analysis between 12 and 37 Mev shows a minimum at about 20 Mev. These data combined with preliminary measurements at higher energies indicate that there is a broad maximum centered at about 40 Mev. The number of protons/(Mev cm^2 sr) at several low-energy points is as follows: at 14.0 Mev, $(4.00\pm0.25)\times10^2$; at 19.7 Mev, $(3.21\pm0.16)10^2$; at 34.1 Mev, $(3.90\pm0.16)\times10^2$. The intensity is several times greater than that observed on our previous flight over approximately the same trajectory.[1] Results of identification of particles heavier than protons observed in this experiment as well as in a previous one will also be presented.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] A. H. Armstrong, F. B. Harrison, H. H. Heckman, and L. Rosen, J. Geophys. Research **66**, 351 (1961).

P7. Effect of Synchrotron Radiation on Van Allen Electrons. David D. Elliott,* *Lockheed Missiles and Space Division.*—Following the magnetic storm of August 16–17, 1959, the three radiation detection experiments on the Explorer VI satellite measured a significant increase of the electron flux in the outer zone of the radiation belt. The observed rate at which the electron intensity then decayed to the prestorm value was different for each of the three instruments (each having a different electron energy threshold), the indication being that high-energy electrons were lost preferentially. The question of energy loss by synchrotron radiation will be examined as a possible explanation of these observations.

* Present address: Aerospace Corporation, Los Angeles, California.

P8. A Measurement of the Low-Energy Neutron Albedo.* W. P. Reidy, R. C. Haymes, and S. A. Korff, *New York University.*—An Aerobee-150A sounding rocket instrumented with 44 BF_3 proportional counters and associated electronics was launched from Wallops Island, Virginia on August 23, 1960, a geomagnetically quiet day, and reached a maximum altitude of 116 miles. The counters were of two different boron isotopic enrichments, which permits the determination of the counting rate due to highly ionizing events. This experiment, which measured neutron density, gave results which are in good agreement with the results of previous measurements by the New York University Cosmic Ray Group in the equilibrium region.[1] The neutron density measured above 50 miles is constant within the accuracy of the measurement. These results are compared with the extrapolation of previous balloon-borne experiments and the calculated flux[2] in this region.

* Supported by the National Aeronautics and Space Administration.
[1] R. C. Haymes and S. A. Korff, Phys. Rev. **120**, 1460 (1960).
[2] W. N. Hess, E. H. Canfield and R. E. Lingenfelter, J. Geophys. Research (to be published).

P9. Increase of the Cosmic-Ray Nucleonic Intensity in November, 1960.* J. A. Lockwood and M. A. Shea, *University of New Hampshire.*—Two increases of about 100% in the cosmic-ray nucleonic intensity were recorded at Mt. Washington and Durham, New Hampshire, on November 12 and 15 following large solar flares. The two increases exhibited different features, and these differences will be discussed in relation to solar phenomena. From a study of the world-wide nucleonic intensity data it appears that: (1) the rigidity spectrum can be expressed as KP^{-n} with $n=6$ for both flares; (2) for the increase on November 12, the time of maximum intensity was earlier for higher rigidity particles, indicating particle dispersion; (3) the classical impact zone theory derived by Firor[1] does not apply for these flares, evidence being presented for the existence of magnetic fields between the earth and the sun.

[1] J. Firor, Phys. Rev. **94**, 1017 (1954).

P10. Mechanism to Establish the Magnetic Storm Ring Current. A. J. Dessler, W. B. Hanson, and E. N. Parker,*

Lockheed Missiles and Space Division.—It is possible to account for the main phase of a geomagnetic storm by means of a belt of protons trapped in the geomagnetic field. It has been argued that these protons were injected into the geomagnetic field by the penetration and diffusion of solar wind particles.[1,2] However recent evidence, which indicates that the solar wind is much weaker than previously supposed,[2] makes such an injection process seem most improbable. It will be shown that hydromagnetic waves generated by the impact of solar plasma on the geomagnetic field form shock waves in the magnetosphere. These shock waves should develop on the nighttime side of the earth and heat the ambient protons (which constitute the normal protonosphere) up to approximately the hydromagnetic wave velocity (of the order of 300 km/sec). The transfer of hydromagnetic wave energy to the protons, then stresses the geomagnetic field to produce the geomagnetic storm main phase.[2]

* Permanent Address: Fermi Institute for Nuclear Studies, Chicago, Illinois.

[1] S. F. Singer, Trans. Am. Geophys. Union **38**, 175 (1957).
[2] A. J. Dessler and E. N. Parker, J. Geophys. Research **64**, 2239 (1959).

P11. On the Cosmic-Ray Storm of November 12-15, 1960.* W. ARTHUR, *New York University.*—A solar flare commencing at 1323 UT November 12, 1960, caused a 110% increase in the cosmic-ray neutron intensity at College, Alaska starting at 1352 UT. The increase was unusual because there was not a sharp rise to maximum intensity. Instead after a rapid rise for one hour, the neutron intensity remained above normal until 1944 UT, when it began another rise until 2030 UT. Then the intensity fell exponentially toward normal until 1115 UT on the 13th, when it fell in a Forbush-type decrease about 20% below prestorm level. A storage mechanism of solar cosmic rays in plasmas emitted from the sun on previous days is proposed. The momentum spectrum of the solar cosmic rays is calculated. The anomolous increase and the Forbush-type decrease are discussed. Finally, a comparison is made with the event on November 15, 1960.

* Supported by the National Science Foundation.

P12. Cosmic-Ray Increases Observed at College, Alaska, at the Time of the November, 1960, Events, and the Acceleration Mechanism.* S. A. KORFF, *N. Y. U.*—Increases in the cosmic-ray intensity observed with a neutron monitor located at College, Alaska, during November, 1960, are reported. Three increases were observed, large ones on November 12 and 15 and a small one on November 20. Correlation with other geophysical variables are noted. The possible interpretation of the event is considered on the basis that both high-energy particles, and a much larger number of low-energy particles are accelerated and emitted by the sun, possibly with some difference in the direction of emission. The spectrum may be a natural result of the energy distribution of the particles in the sun before the acceleration starts.

* Supported in part by the National Science Foundation and in part by the Office of Scientific Research of the U. S. Air Force.

P13. Magnetohydrodynamic Waves in the Ionosphere.* HOWARD H. C. CHANG, *Hughes Research Laboratories.*—In a recent paper, Francis and Karplus studied the propagation of MHD waves in a horizontally stratified ionosphere composed of electrons, ions, and neutrals, whose properties are in agreement with the latest IGY data. For the very low frequencies of interest, $f=1$ cps, the earth was assumed to be a perfect conductor, and for simplicity they considered only the case of a vertically incident plane monochromatic wave near 45° geomagnetic latitude. Machine integration of the relevant equations was necessary because the geometrical optics approximation is invalid. After a discussion of the physical basis and validity of the assumptions which are made by Francis and Karplus, their work is generalized to the case of an obliquely incident MHD wave. Following Clemmow and Heading, the equations governing the behavior of the field quantities are cast in the "coupled form" suitable for computation by means of a high-speed modern computer. Because of the prohibitive amount of work necessary to solve the equations and to satisfy the boundary conditions in the case of oblique incidence and in the nongeometrical optics limit, no numerical results have been obtained.

* Sponsored by the Electronics Research Directorate of the Air Force Cambridge Research Center, ARDC.

P14. Beta-Ray Spectrometer for Space Physics Experiments Utilizing an Array of Semiconductor Detectors. H. L. WEST, S. D. BLOOM, AND L. G. MANN, *Lawrence Radiation Laboratory, Livermore,* AND S. S. FRIEDLAND, R. M. OLSON, AND F. P. ZIEMBA, *Solid State Radiations, Inc.*—A versatile, small, and rugged multichannel electron spectrometer for space experimentation has been developed, evaluated, and calibrated. A linear array of 10 semiconductor detectors is aligned in the focal plane of a 180° permanent-magnet beta-ray spectrometer covering an energy range from 50 kev to 1240 kev, with channel energy widths varying from 75 to 150 kev. Each channel consists of a detector, preamplifier, main amplifier, discriminator, and scaler. A discussion of the mechanical design, detector properties, electronic circuitry, calibration procedures, and intended experiments will be given.

FRIDAY AT 14:30

Auditorium 2 (C.M.)

(F. ALBA ANDRADE presiding)

Symposium on Experimental Nuclear Physics

PA1. Absolute Determination of Nuclear Cross Sections. FERNANDO ALBA ANDRADE, *Universidad Nacional Autónoma de México.* (40 min.)

PA2. Treatment of Many-Body Nuclear Decay as a Sequence of Two-Body Reactions. G. C. PHILLIPS, *Rice University.* (30 min.)

PA3. Some Alpha-Particle Experiments with a Tandem Van de Graaff Accelerator. R. H. DAVIS, *Florida State University.* (30 min.)

PA4. Nanosecond-Resolution Neutron Velocity Spectrometer Involving a Synchrocyclotron. W. W. HAVENS, JR., *Columbia University.* (30 min.)

FRIDAY AT 14:30

Auditorium 6 (C.M.)

(R. V. POUND presiding)

Magnetic Resonance: Masers

Q1. Nuclear Spin of Scandium-46.* F. R. PETERSEN AND H. A. SHUGART, *University of California, Berkeley.*—The nuclear spin $I=4$ for radioactive scandium-46 ($\tau_{\frac{1}{2}}=84$ days) has been measured by the atomic-beam magnetic-resonance method. Three "flop-in" transitions in the $^2D_{\frac{3}{2}}$ electronic state and two in the $^2D_{\frac{5}{2}}$ electronic state have been observed at various fields from 5 to 75 gauss. These resonances provide unambiguous evidence for the assigned spin value and furnish preliminary values for the hyperfine-structure separations and nuclear moments of the isotope. The radioisotope was produced from stable metal by the reaction $Sc^{45}(n,\gamma)Sc^{46}$ in the Livermore pool-type reactor. Purity and identification of the isotope were established by pulse-height analysis of the gamma-ray spectrum. Resonance detection was accomplished by collecting the beam on sulfur-coated "buttons" which were subsequently counted in continuous-flow beta counters.

* Supported in part by the Air Force Office of Scientific Research and the U. S. Atomic Energy Commission.

Q2. Nuclear Relaxation in Gaseous Mixtures.* J. S. WAUGH AND C. S. JOHNSON, JR., *Massachusetts Institute of Technology.*—T_1 for the protons in H_2 has been measured between 2 and 40 atm and between 77° and 300°K in normal hydrogen and in mixtures with several other gases. T_1 is linear in the numerical densities of all species, in accord with Schwinger's[1] mechanism of relaxation by intramolecular interactions. m_J transitions are much less probable (0.01 to 0.3) than transfers of linear momentum (determined from transport properties). Their frequencies agree in order of magnitude with estimates using the sudden approximation applied to molecular electric multipole interactions alone. In pure H_2, T_1/density is independent of temperature above 100°K, as observed by Bloom and Lipsicas, but measurements on other systems indicate that this is a complicated special case. When intramolecular interactions are weak and a paramagnetic species is present there are deviations from the above behavior at the higher densities. In mixtures of CH_4 and O_2 the dependence of T_1 on density, composition, and temperature is well described by a simple collisional model incorporating the relaxation mechanisms of Bloembergen and BPP[1] in addition to that of Schwinger.

* Supported in part by the Army Signal Corps, the Air Research and Development Command, and the Office of Naval Research, and in part by the Alfred P. Sloan Foundation.

[1] N. Bloembergen, E. M. Purcell, and R. V. Pound, Phys. Rev. **73**, 679 (1949).

Q3. Translational and Rotational Contributions to Nuclear Spin-Lattice Relaxation in Benzene.* M. EISNER AND R. W. MITCHELL, *Texas A & M College.*—T_1 measurements have made on protons in C_6H_6-C_6D_6 solutions. The rotational contribution to the relaxation of benzene protons is obtained from the infinite dilution value inferred by extrapolation. $1/T_1$ is found to be a linear function of volume fraction and the translational contribution is found from the difference of $1/T_1$ for the pure C_6H_6 and the infinite dilution $1/T_1$. The rotational and translational relaxation times found in this manner are 60 and 30 sec, respectively. The rotational correlation time is calculated using a previously described model[1] and found to be 2.0×10^{-12} sec in reasonable agreement with 2.3×10^{-12} sec, the value inferred from the rotational relaxation time. Using the value of the diffusion coefficient measured by spin-echo techniques, a translational relaxation time of 30 sec is obtained assuming the distance of closest approach during collision to be 5.0×10^{-8} cm.

* Supported by the Office of Scientific Research, U. S. Air Force.

[1] R. W. Mitchell and M. Eisner, J. Chem. Phys. **33**, 86 (1960).

Q4. Quadrupole Interaction of Li^7 in the Ferroelectrics, $LiH_3(SeO_3)_2$ and $LiD_3(SeO_3)_2$.* DAVID H. ANDERSON, *Sandia Laboratory.*—The interpretation of the Li^7 quadrupole coupling data in single crystal $LiH_3(SeO_3)_2$ is difficult because of small splittings and two nonequivalent crystallographic sites. However, in a single crystal of $LiD_3(SeO_3)_2$ which was γ irradiated to reduce the spin-lattice relaxation time, better resolution was obtained, presumably because of the weaker magnetic environment. The Li^7 constants from $LiD_3(SeO_3)_2$ were consistent with the data from $LiH_3(SeO_3)_2$. Both sites had the same coupling constant, $(eqQ/h)=3.5\times10^4$ sec^{-1}, and the same asymmetry parameter, $\eta=0.5$, within experimental error. The principal axis at each site had different directions; in each case it was approximately along a line connecting the Li^+ ion with a near oxygen ion. (This is based on the probable Li positions given by Vedam *et al.*[1]) Thus the Li^+ ions apparently play a role in fairly short oxygen-oxygen distances,[1] analogous to hydrogen bonds. This encourages the speculation that perhaps the Li^+ ions in $LiH_3(SeO_3)_2$ have a function similar to hydrogen ions in the "hydrogen-bonded" ferroelectrics, such as KH_2PO_4.

* Work performed under the auspicies of the U. S. Atomic Energy Commission.

[1] K. Vedam, Y. Okaya, and R. Pepinsky, Phys. Rev. **119**, 1252 (1960).

Q5. Nuclear Quadrupole Resonance of Cl in Paramagnetic $CoCl_2{\cdot}H_2O$. W. W. SIMMONS, W. A. ROBINSON, AND W. J. O'SULLIVAN, *Space Technology Laboratories.*—The Cl^{35} and Cl^{37} NQR have been observed in powder samples of paramagnetic $CoCl_2{\cdot}6H_2O$ with a superregenerative detector. The Cl^{35} resonance is fairly strong with linewidth of approximately 15 kc and a frequency of 5.54 Mc at 4.2°K. The resonance disappears abruptly at 2.3°K in good agreement with the Néel temperature as observed by Robinson and Friedberg[1] from specific heat measurements, but slightly lower than the Néel temperature deduced from proton NMR by Sugawara.[2] Neglecting all overlap effects, and correlation between different Co^{++}-Cl^- bonds, an estimate of the departure of the system from the ionic configuration $Co^{++}(3d^7)Cl^-(3p^6)$, is derived from the observed resonance frequency. This result indicates that the ionic configuration represents a reasonable first approximation in $CoCl_2{\cdot}6H_2O$.

[1] W. K. Robinson and S. A. Friedberg, Bull. Am. Phys. Soc. **4**, 183 (1959).
[2] T. Sugawara, J. Phys. Soc. Japan **14**, 1248 (1959).

Q6. Investigations of the Fault Structure Resonances in Cobalt Metal. W. A. HARDY, *IBM Corporation, Owego.*—In addition to the resonances reported previously, several additional nuclear resonances have been detected in pure cobalt powders and films originating in the fcc or hcp phases and in associated fault structure.[1] A systematic investigation of all of these will be reported, including the temperature dependence of the resonant frequencies, intensities, and linewidths as well as further identification of the fault lines based on metallurgical treatment and x-ray analysis. Portis' explanation of the observed dispersion shape of the absorption,

based on the nonsaturation of the dispersion according to Redfield's theory, is additionally confirmed by the observation of the phase change of the resonant signal at very low rf field levels—this also introduces a technique for measurement of the enhancement factor, giving the rf field by which the nucleus is driven in the metal, and relating this to the sample metallurgy. Cold working of a number of samples has produced severe line broadening due to strain and the relief of this with temperature and time can be followed by direct monitoring of the resonances.

[1] W. A. Hardy, J. Appl. Phys. **32**, 122S (1961).

Q7. Recoil-Free Resonant Absorption in Tm^{169}. R. L. COHEN, U. HAUSER, AND R. L. MÖSSBAUER, *California Institute of Technology*.—The recoil-free nuclear resonance absorption of the 8.4-kev transition in Tm^{169} which is emitted in the decay of 9.4-day Er^{169} has been investigated. The low energy of the transition results in a high fraction of recoil-free transitions even at high temperatures. With sources and absorbers in the metal and oxide forms, hyperfine structures have been obtained which are strongly temperature dependent. The observed absorption patterns are explained on the basis of a quadrupole interaction resulting from the interaction of the nuclear quadrupole moment of Tm^{169} in its excited state (spin $\frac{3}{2}$) with an average electrical field gradient produced by the surrounding electrons. In the case of the oxide samples the pattern is complicated by the fact that the rare-earth ions are found in two lattice sites of nonequivalent symmetry. The magnetic hyperfine interaction is expected to be negligible. Arguments for this are given on the basis of the short spin-relaxation times in compounds of the rare earths.

Q8. Paramagnetic Resonance of Ce^{3+} in $La(C_2H_5SO_4)_3 \cdot 9H_2O$ at 71 kMc/sec. D. P. DEVOR AND R. H. HOSKINS, *Hughes Research Laboratories*.—The paramagnetic resonance of Ce^{3+} in a lanthanum ethyl sulphate host lattice has been observed at a frequency of 71 kMc/sec at a temperature of 1.4°K. Bogel *et al.*[1] have observed the resonance of two doublets in this system and reported the g values and estimated the zero field splitting between the doublets at 3 ± 1 cm^{-1}. At 71 kMc/sec we have observed the same Zeeman splitting as Bogel *et al.*, and by observing a transition between the doublets have measured the zero field splitting as 118.2 ± 0.1 kMc/sec or 3.94 cm^{-1}. A crystalline field theory sufficient to account for the spectrum as observed by Bogel *et al.* was developed by Elliott and Stevens[2] and we have used their theory to calculate the transition probabilities. A comparison of the intensities of the lines observed indicates the transition between doublets to be about an order of magnitude stronger than predicted. Possible interpretations of our results will be discussed.

[1] G. S. Bogel, A. H. Cooke, and S. Whitley, Proc. Phys. Soc. (London) **A64**, 931 (1951).
[2] R. J. Elliott and K. W. H. Stevens, Proc. Roy. Soc. (London) **A215**, 437 (1952).

Q9. Paramagnetic Relaxation in solutions—Interionic Effects. R. G. PEARSON AND T. BUCH, *Northwestern University* (introduced by A. A. Frost).—The magnetic interaction between two different paramagnetic ions in solution provides a path for their mutual relaxation, leading to an increase in their ESR linewidths. The relative values of two "times" determine the nature of this effect: the lifetime of a spin state in the "collision complex" formed between the two ions; and the lifetime of a collision complex proper, that is, the time the two ions spend in such close vicinity to each other that the magnetic dipole interaction is effective in producing relaxation. Whichever of these times is longer will determine the rate of relaxation. In principle, the two limiting cases can be distinguished experimentally by the way the linewidth depends on the concentration of the paramagnetic species. In this study, the effect of metal ions of the first transition series in complexes of various charge types, plus several lanthanide ions, on the linewidth of the peroxylamine-disulfonate radical ion was investigated. The results essentially agree with what is expected from calculations based on the theory of kinetic effects in ionic solutions. The rates of ion-pair formation were found in a number of cases, and agree with the predictions for a diffusion controlled reaction modified by electrostatic effects.

Q10. Polarization of Nuclei in Liquids by Contact with a Paramagnetic Solid. JEAN UBERSFELD, *University of Besançon, France*.—It has been shown that if nuclear spins experience a *static* dipole interaction with electron spins, the nuclear polarization can be enhanced by a factor of order of $\gamma e/\gamma n$ (where γe and γn are, respectively, the electron and nuclear gyromagnetic ratio). The enhancement is obtained by saturating one of the two "forbidden" transitions corresponding to a mutual nuclear and electron spin flip in a given magnetic field. This type of nuclear polarization has been observed on protons of liquids surrounding particules of paramagnetic chars. The reason for this result is the existence of an adsorbed part of the liquid on the surface of the char, where the nuclear spin experiences static interaction with the electron spin of the solid and a rapid exchange between molecules of the adsorbed part and molecules of the bulk liquid. Studies of such dynamic polarization has been made on protons of liquid benzene surrounding different type of chars. The dynamic polarization which we have obtained in this case is about 50 times that at thermal equilibrium (the maximum theoretical value is 660). Such experiment should be possible to polarize liquid hydrogen and liquid helium 3 at low temperature. If we extrapolate the result actually obtained with benzene at room temperature—which seems to be reasonable, and even pessimistic—we would expect a nuclear polarization of about 0.5% for liquid hydrogen at 10°K and 10% for liquid helium 3 at 0.5°K in a field of about 10 kgauss.

Q11. Cyclotron Resonance in Gases.* D. KIVELSON, K. BAYES, AND S. C. WONG, *University of California, Los Angeles*.—We have used a conventional ESR spectrometer to study the cyclotron resonance in the products of discharge in various gases. A TE_{102} rectangular cavity was used with the rf E field almost parallel to the applied magnetic field; this enabled us to use enough power to sustain an adequate bias on the detecting crystal without heating the electrons appreciably. The gas flowed continuously through the cavity, which was located about 50 cm from the discharge. It appears that some of the electrons observed diffuse down from the discharge; others are formed in the afterglow. Molecular gases were introduced downstream from the discharge and the observed broadening of the cyclotron resonance lines could be used to estimate molecular cross sections to electron impacts. Only low-power measurements are significant because at high electron temperatures the mean free path is velocity dependent, which makes the result difficult to interpret.

* Supported in part by the National Science Foundation and the Research Corporation.

Q12. Transient Behavior of a Parallel-Pumped Ferromagnetic Amplifier. C. S. PORTER, C. A. MORRISON, AND L. A. AULT, *Diamond Ordnance Fuze Laboratories*.—Using a parallel-pumped yttrium iron garnet single crystal amplifier pumped at 9.2 kMc, we have determined the output signal as a function of frequency and amplitude modulation of the pump, of the signal, of the magnetic field, and of variations of loading of the signal and idler modes. From these data, we

can estimate the noise output expected in the signal due to these sources. It is possible also to estimate the effective loaded relaxation times of the modes. The threshold for oscillation is increased and the gain of the amplifier decreased by the modulation, in agreement with Suhl's letter on the stabilization of resonance by modulation.[1]

[1] H. Suhl, Phys. Rev. Letters 6, 174 (1961).

Q13. Quantum Optics of Coherent Radiation from Masers. JENNY E. ROSENTHAL, *Bramley Consultants.*—The possibility of focusing a coherent radiation beam into an area of the order of its wavelength raises questions on applicability of classical optics. For emitted light intensity at $\lambda=6943$ A of 10^4 w/cm^2, as in Maiman's optical maser, the photon density at the focus is 2.4×10^{20} photons/cm^3 (or nearly 1% of the number of atoms per cm^3 in crystalline silicon). This results in 140-Mev energy in a volume of the order of λ^3. The electric and magnetic field intensities are 4×10^7 v/cm and 10^5 oe, respectively, while radiation pressure exceeds 600 atm. Stipulating these conditions, we consider the following: If two states of an isolated atomic system are $2h\nu$ apart, how does the probability of excitation to the upper state by absorption of two photons, each of energy $h\nu$, compare with probability of the same excitation by absorption of one $h(2\nu)$ photon? Is the probability of multiple photon absorption sufficient for stripping of atoms? Here μ_0 and ϵ_0 are assumed to retain their usual values in Maxwell's equations for propagation *in vacuo.*

Q14. Electromagnetic Modes of an Optical Maser. E. S. DAYHOFF, *U. S. Naval Ordnance Laboratory.*—A theory of wave propagation originally developed for treating the effects of diffraction in microwave interferometry is adapted to the discussion of the modes of oscillation of an optical maser having plane-parallel ends. In this theory,[1] which provides a rigorous formulation of electromagnetic wave propagation in propagation vector space by use of a sort of scattering matrix representation, it is possible to represent explicitly the effects of diffraction and to treat diffraction effects as a perturbation on an undiffracted wave in a unified way. The resulting equations are complicated but the nature of the solutions may be readily seen as a consequence of the perturbation procedure. The characteristic wave solutions in the presence of diffraction may be expressed as linear superpositions of those solutions which would exist in the absence of diffraction, i.e., the ordinary solutions of the Fabry-Perot type. The new solutions differ qualitatively from the old in that: (1) there is a spread of propagation directions in each characteristic solution and (2) most of the spacial nodes of the old solutions are removed or weakened by the mixing of simple modes.

[1] D. M. Kerns and E. S. Dayhoff, J. Research Natl. Bur. Standards **64B**, 1 (1960).

FRIDAY AT 14:30

Auditorium 7 in "B" Building (C.M.)

(JOSEPH MATHER presiding)

Symposium of the Division of Plasma Physics

QA1. Transport Properties of Fully Ionized Gases. I. BERNSTEIN, *Project Matterhorn.* (30 min.)

QA2. Geometry of Magnetic Confinement. J. L. TUCK, *Los Alamos Scientific Laboratory.* (30 min.)

QA3. Cyclotron Radiation from Thermonuclear Plasmas. W. E. DRUMMOND, *General Atomic.* (30 min.)

QA4. Measurement of Plasma Temperature. H. R. GRIEM, *University of Maryland and U. S. Naval Research Laboratory.* (30 min.)

FRIDAY AT 14:30

Auditorium 4 (C.M.)

(M. MOSHINSKY presiding)

Theoretical Physics II

R1. Minimum Principle for Effective Ranges.* LEONARD ROSENBERG, THOMAS F. O'MALLEY, AND LARRY SPRUCH, *New York University.*—Ohmura has recently given a variational principle for the effective range r_0 for s-wave scattering which has the additional property that second-order variations about the true solution are positive (i.e., there is a local minimum) provided that the scattering length is known precisely. We have shown that under the above conditions the exact solution lies at an *absolute* minimum, not merely a local minimum. Further, for $L>0$ we again obtain an absolute minimum principle where now the "scattering length" A_L need not be known *a priori.* The improved results follow from the identity

$$\tfrac{1}{2}r_{0L}A_L^2=\tfrac{1}{2}r_{0Lt}A_{Lt}^2-(u_{1t},H^2u_{1t})+(w_1,H^2w_1),$$

where u_{1t} and w_1 are proportional to the coefficients of the linear terms in the energy expansions of the trial scattering function u_t and the difference function $w=u_t-u$, respectively; u satisfies $(H-E)u=0$. The stated results are obtained by noting that the second integral above is positive (the normalization of u and u_t is crucial here). Comparable results may be obtained for repulsive Coulomb fields, even for $L=0$.

* Sponsored in part by the AFCRL, the OOR, and the ONR.

R2. Absorption of Radiation in Quasi-Classical Model. D. F. DUBOIS AND M. G. KIVELSON, *The Rand Corporation.*—Starting from the generalized Hartree-Fock (HF) theory as expressed in the Green's functions formalism,[1] we develop an expansion of the spectral density, which has the Thomas-

Fermi-Dirac (TFD) description as its lowest-order contribution. Using this expansion we calculate the absorption coefficient in the quasi-classical limit. The result can be expressed as an integral depending only on the TFD potential. Comparison is made with the results of more exact quantum-mechanical treatments, such as HF. The Green's functions calculated by the methods above provide a zero-order solution from which the correlation corrections may be obtained using the techniques developed by Gell-Mann and Brueckner[2] for the electron gas.

[1] P. C. Martin and J. Schwinger, Phys. Rev. **115**, 1342 (1959).
[2] M. Gell-Mann and K. Brueckner, Phys. Rev. **106**, 364 (1957).

R3. On the Equations Governing the Coherence of the Radiation Emitted by Random Charge and Current Distributions. M. BERAN AND G. PARRENT, JR., *Technical Operations Inc.*—In the field of physical optics, coherence theory[1] has proved a very useful concept in analyzing optical phenomena. An extension of this theory to include source terms provides the framework for using optical measurements to obtain information about the statistical current and charge correlations in an optically thin plasma. In this paper we shall derive from Maxwell's equations the differential equations relating the correlation tensors to the current and charge correlations. The correlation tensors associated with the E and H fields are defined, respectively, as

$$\mathcal{E}_{jk}(\mathbf{x}_1,\mathbf{x}_2,t_1,t_2) \equiv \{E_j(\mathbf{x}_1,t_1)E_k^*(\mathbf{x}_2,t_2)\}$$

and

$$\mathcal{H}_{jk}(\mathbf{x}_1,\mathbf{x}_2,t_1,t_2) \equiv \{H_j(\mathbf{x}_1,t_1)H_k^*(\mathbf{x}_2,t_2)\},$$

where the brackets indicate an ensemble average. The equations are derived for both the stationary and nonstationary cases. The usefulness of these results stems from the consideration that at optical frequencies the correlation tensor of the E field may be determined by interferometric techniques. Thus, as a diagnostic tool, this tensor contains within it, not only the spectral distribution but also information about the space-time correlations of the currents and charges comprising the plasma.

[1] Born and Wolf, *Principles of Optics* (Pergamon Press, New York, 1959), Chap. X.

R4. KLL Auger Transition Probabilities. EDWIN J. CALLAN, *Wright-Patterson AFB.*—KLL Auger transition rates have been computed for a variety of atomic numbers between 1 and 80, for all transitions involved. Screened nonrelativistic hydrogenic wave functions were used. Screening constants were derived from limiting screening numbers for SCF functions,[1] modified for nonzero values of mean radius. Ejected electron energies were obtained from energy level values. Transition amplitudes based on L-S coupling[2] are also presented. Variations in transition rates for independent changes in effective atomic charge and Auger electron energy are given for several atoms. Increases in transition rates with Z are smooth, but vary in different fashions. The $^1D_2$ and $^1P_1$ amplitudes show much greater increase with Z than do $^1S_0$ or $^3P_2$ amplitudes, for example. In L-S coupling, the relative amplitudes for total angular momentum $L=1$ and 2 are opposite in strength to those found using relativistic theory.[3] Some K-shell fluorescence yields were computed, and are compared with other values.

[1] C. Froese, C. Proc. Roy. Soc. (London) **A239**, 311 (1957); **A244**, 390 (1958).
[2] W. Asaad and E. H. S. Burhop, Proc. Phys. Soc. (London) **71**, 369 (1958).
[3] W. Asaad, Proc. Roy. Soc. (London) **A249**, 555 (1959).

R5. Perturbation of the Lithium Atom by a Point Charge.* JOSE LUIS CORTEZ AND J. M. ROBINSON, *Texas College of Arts and Industries.*—The "ground" and first "excited" states of the lithium atom were studied in a detailed calculation using a point charge (+1) as the perturber. The system was treated in a quasi-static manner for different separation distances R to determine the behavior of the electronic charge distributions of the Li atom under perturbation. The screening parameters were varied extensively to arrive at the best set for the perturbed atom. The best description of the system, with the restricted set of configurations used, generated different screening parameters for the "ground" and "excited" states. Calculations were made using a program which was coded for the Univac Scientific 1103 at Southern Methodist University Computing Center by one of the authors (JLC). Expectation-energy values plotted for different R's showed a minimum around $R=3.5$ a.u. The results of the calculation gave the expected shift to the red for the $^2S_{\frac{1}{2}}-{}^2P_{\frac{1}{2}}$ transition. It was noted that the $2s$ function was more sensitive to changes in R than the $2p_z$, while the $1s$ description was relatively constant for values of $R \geqq 3$ a.u.

* Supported by the National Science Foundation.

R6. Perturbation of Three Electron Atomic Systams by a Point Charge.* J. M. ROBINSON AND JOSE LUIS CORTEZ, *Texas College of Arts and Industries.*—The electronic charge distributions of the isoelectronic series of Li were studied under the perturbation of a point charge in detailed calculations which allowed for the variation of the screening parameters in both the "ground" and "excited" states. Correlations are made between the Z of the nucleus, the separation distances, and various observables. Calculations were made on the Univac Scientific 1103 at Southern Methodist University using a completely automatic program written by one of the authors (JLC).

* Supported by the National Science Foundation.

R7. Partial-Wave Dispersion Relations for Nucleon Compton Scattering. A. P. CONTOGOURIS, *Cornell University.*—The scattering of photons by nucleons to the order e^3 is treated from the Mandelstam point of view. The angular-momentum decomposition for the processes $\gamma+N \rightarrow \gamma+N$ and $\gamma+\gamma \rightarrow N+\bar{N}$ is carried out. The analytic properties of the partial wave amplitudes are then determined from the double representation. The discontinuities across the unphysical branch cuts are calculated with the help of the symmetry properties satisfied by the invariants of the problem and of analytic continuation through Legendre polynomials. In this way a set of coupled dispersion relations for the partial waves is derived, which involve the amplitudes for the scattering and production processes above. The limits of validity of the Legendre expansion are discussed and an application on proton Compton scattering with the inclusion of the most significant multipoles is considered.

R8. Variational Principles for a Vector Field in Scattering Theory. R. J. WAGNER, *Space Technology Laboratories.*—Variational methods are considered for the solution of the vector wave equation describing the field due to an arbitrary source placed in the neighborhood of an inhomogeneous absorbing medium. Variational principles for the tensor Green's function satisfying the point source equation,

$$\nabla\times\nabla\times G(\mathbf{r},\mathbf{r}') - k^2 G(\mathbf{r},\mathbf{r}') + U(\mathbf{r})G(\mathbf{r},\mathbf{r}') = -I\delta(\mathbf{r}-\mathbf{r}'),$$

have been obtained in linear and exponential forms, analogous to the Altshuler principles for the scalar wave function.[1] Stationary forms for the standard scattering problem (incident plane wave, outgoing solutions) are recovered when the point source recedes to infinity. As in the scalar case the bifunctional character of the stationary forms in the asymptotic region results as a natural limit of the point source variational principles.

[1] S. Altshuler, Phys. Rev. 109, 1830 (1958).

R9. On the Redundant Poles of the Scattering Matrix. J. M. LOZANO, *Instituto de Física, Mexico.*—It is well known that in the scattering of a nonrelativistic particle by a fixed potential, the scattering matrix $S(k)$ as a function of the complex wave number k, allows redundant poles for infinite range potentials; on the other hand, if the potential has a finite range a, the corresponding S matrix has no such poles. We may then conclude that these poles arise from the tail of the potential. From the study of two simple examples, i.e., the Eckart and the Bargmann potentials, cut at a distance a and considering the corresponding $S_c(k,a)$ when a becomes infinity, i.e., when the potential's tail effect is introduced, we show how the redundant poles appear. For the Eckart potential, the S matrix has a redundant pole on the positive imaginary axis, and for the Bargmann potential it has two redundant poles, one on the first and the other on the second quadrant.

R10. Polarization ahd Correlation Tensors in Electron-Hydrogen Atom Scattering. P. G. BURKE, *Lawrence Radiation Laboratory, Berkeley,* AND H. M. SCHEY, *Lawrence Radiation Laboratory, Livermore.*—We have derived explicit forms for the polarization and correlation tensors arising in electron-hydrogen atom scattering equivalent to the expressions given by Schumacher and Bethe[1] for nucleon-nucleon scattering. Expressing these in terms of the singlet and triplet scattering amplitudes we are then able to calculate them using phase shifts obtained by various authors. Plots of the tensors will be given showing their variation with scattering angle and energy and comments will also be made concerning their usefulness in resolving different theoretical solutions to the electron-hydrogen atom scattering problem.

[1] C. R. Schumacher and H. A. Bethe, Phys. Rev. **121**, 1534 (1961).

R11. On the Theory of Inelastic Scattering. F. MEDINA AND L. ESTRADA, *Instituto de Física, Mexico.*—The inelastic scattering process is discussed using a two-channel model based on Feshbach's unified theory of nuclear reactions.[1] The exact solution is obtained assuming square wells for all "coupling potentials." The resonant process in analyzed and compared with the corresponding one obtained from Moshinsky's description of nuclear reactions by boundary conditions.[2] Finally, the meaning of the coupling between the entrance and exit channels is discussed.

[1] H. Feshbach. Ann. Phys. **5**, 537 (1958).
[2] M. Moshinsky. Phys. Rev. **81**, 347 (1951); F. Medina (to be published).

R12. Elastic Scattering of Relativistic Electrons by Screened Nuclei.* R. T. BROWN, S. R. LIN, AND N. SHERMAN, *University of Michigan.*—The elastic scattering of relativistic electrons by exponentially screened nuclei has been calculated numerically. The main quantities of interest are the polarization asymmetry factor,[1] $S(\theta)$ and the single-scattering cross section. Results for $Z=79$ at electron kinetic energy 121 kev are presented for comparison with related calculations.[1,2] The scattering was computed from the phase shifts. The phase shifts were obtained by numerical integration of the radial Dirac equations by two independent methods. They were also checked against corresponding WKB phase shifts. Intermediate numerical results (such as scattering amplitudes and phase shifts) were recorded and are available for use in other calculations. Computations were performed on the IBM 704's at the University of Michigan and at the Institute of Mathematical Sciences of New York University.

* Supported in part by the National Science Foundation, the Office of Naval Research, and the U. S. Atomic Energy Commission.
[1] N. Sherman and D. F. Nelson, Phys. Rev. **114**, 1541 (1959).
[2] C. B. O. Mohr and L. J. Tassie, Proc. Phys. Soc. (London) **67**, 711 (1954).

R13. An Optical Model Description of the Elastic Scattering of 8-Mev Protons.* MARTIN L. GURSKY AND LEONA STEWART, *Los Alamos Scientific Laboratory.*—The angular dependence of the elastic scattering of approximately 8-Mev polarized protons recently measured[1] at Los Alamos was subjected to an optical-model analysis. With the exception of the nuclear radius, parameters were chosen identical to those used in a similar analysis of the scattering of 10-Mev protons.[2] The trends of prediction and observation were compared for targets from He to Zn. By changing r_0 the assumed nuclear potential radius parameter, from the original 1.20 f[2] to 1.25 f the optical-model calculations follow the experimentally observed trends with reasonable fidelity. No attempt was made to obtain "best fits" to individual elements nor to establish the uniqueness of the parameters employed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Rosen, *Proceedings of the International Conference on Nuclear Structure* (Kingston, Ontario, 1960) p. 185.
[2] L. Rosen, J. E. Brolley, Jr., and L. Stewart, Phys. Rev. **121**, 1423 (1961).

R14. Optical-Model Analysis of Elastic Scattering of Protons by Carbon at 11 to 20 Mev.* J. S. NODVIK, *University of Southern California,* C. B. DUKE, *Princeton University,* AND M. A. MELKANOFF, *University of California, Los Angeles.*—An extensive analysis of the elastic scattering of protons by carbon over the energy range 11–20 Mev has been carried out with an optical-model potential which includes a Gaussian surface absorption and a spin-orbit coupling. Experimental data at small energy intervals from several laboratories was fitted by means of an automatic search program utilizing UCLA's IBM 709 and 7090 computers. This analysis has yielded remarkably good fits to the differential cross sections and qualitative fits for the polarizations and reaction cross sections. The values of the model parameters and their behavior as a function of energy is generally reasonable except that the surface thickness a associated with the real part of the potential shows some systematic increase with energy, and the surface absorption is generally limited to a thin shell. Anomalous behavior of the parameters in the 17 to 18-Mev region will be discussed.

* Supported in part by the National Science Foundation, the Air Force Office of Scientific Research, and the U. S. Atomic Energy Commission.

FRIDAY AT 20:30

Hotel del Prado

(F. ALBA ANDRADE AND F. SEITZ presiding)

Banquet of La Sociedad Mexicana de Física and of The American Physical Society

After-dinner speakers to be announced.

SATURDAY AT 10:00

Auditorium 6 (C.M.)

(W. W. HAVENS, JR., presiding)

Neutron Physics I

S1. A Liquid Helium Scintillator as a Neutron Polarization Analyzer.* R. B. PERKINS AND J. E. SIMMONS, *Los Alamos Scientific Laboratory.*—The polarization of neutrons is conveniently analyzed by scattering from helium. The discovery that liquid helium scintillates,[1] coupled with the advantages of the high density, has led to the development of the liquid helium scintillator described. Coincidence operation between the neutron recoil in the helium and an external neutron counter serves to reduce background. The cryostat design is conventional, utilizing a heat shield at liquid nitrogen temperature. The liquid helium, contained in a glass vessel, is viewed by a photomultiplier tube mounted external to the cryostat. A thin layer of diphenylstilbene is deposited on the inside of the glass to act as a wave shifter. A reservoir of 0.7-liter capacity maintains the liquid helium in the scintillation volume for an 8-hr period. Details of the construction, optics, and behavior as a neutron polarimeter at energies near 20 Mev will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] H. Fleishman, H. Einbinder, and C. S. Wu, Rev. Sci. Instr. **30**, 1130 (1959).

S2. Neutron and Gamma-Ray Spectrometer.* J. D. HALL AND J. B. ASHE, *Texas Nuclear Corporation.*—An organic scintillator spectrometer based on the pulse shape discrimination method[1,2] for neutron and gamma-ray separation is described. Both neutron or gamma ray spectra have been obtained over a range corresponding to neutron energies of 0.5 Mev to 14 Mev with good rejection of the unwanted radiation. A major feature of the spectrometer is its relative insensitivity to photomultiplier voltage in descriminating against either type radiation. Data illustrating the response of the spectrometer to mixed radiation will be presented.

* Supported by Wright Air Development Division, Materials Laboratory.
[1] F. D. Brooks, AERE NP/GEN 8 (1959).
[2] M. Forte, *Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy* (United Nations, New York, 1958), Vol. 14, Paper P/1514, p. 300.

S3. A Total Absorption Gamma-Ray Spectrometer.* I. L. MORGAN, J. T. PRUD'HOMME, AND J. B. ASHE, *Texas Nuclear Corporation.*—An anticoincidence annulus gamma-ray spectrometer of the type developed by Trail and Raboy[1] has been used in conjunction with a nanosecond pulsed-beam time-of-flight system to obtain gamma-ray spectra due to the interaction of neutrons with various elements. Energy resolution and gamma-ray-detection efficiency curves will be presented. Typical results for 4 Mev and 15 Mev neutrons with various modes of gating will be discussed.

* Supported in part by the U. S. Atomic Energy Commission.
C. C. Trail and Sol Raboy, Rev. Sci. Instr. **30**, 425 (1959).

S4. Gamma Rays From Inelastic Scattering of 4.1 Mev Neutrons.* J. B. ASHE, J. H. MCCRARY, D. O. NELLIS, AND O. M. HUDSON, JR., *Texas Nuclear Corporation.*—Using the system described in the previous abstract, gamma-ray pulse height spectra due to the interaction of 4.1 Mev neutrons with Al, Fe, Ni, and Cu have been obtained. Table I lists the energies of gamma rays observed. Relative intensities of the gamma rays will be presented.

TABLE I. Observed gamma rays (Mev).

Al	Fe	Ni	Cu
0.84	0.84	0.82	0.66
1.01	1.04	1.00	0.95
1.71	1.23	1.16	1.11
2.23	1.80	1.33	1.33
2.79	2.12	1.43	1.84
3.10	2.29	1.79	2.32
	2.60	3.16	2.89
	3.68	3.40	3.60

* Supported in part by the U. S. Atomic Energy Commission.

S5. A Neutron Time-of-Flight System for Use with a Cyclotron.* H. W. FULBRIGHT, J. W. VERBA, AND V. K. DESHPANDE, *University of Rochester.*—A time-of-flight apparatus based on the naturally pulsed character of the beam of a conventional cyclotron has been developed for use with the variable energy cyclotron at the University of Rochester. Time-difference-to-pulse-height conversion is employed, the circuit being a transistorized version of that used by Cranberg and his collaborators at Los Alamos. Reverence pulses are derived from the cyclotron oscillator. Time resolutions ranging from 1.5 to 3 nsec are obtained depending upon conditions, with p, d, He^4, and He^3 beams.

* Work supported by U. S. Atomic Energy Commission.

S6. Study of $Be^9(\alpha,n)C^{12}$ and $C^{13}(\alpha,n)O^{16}$ Reactions at α Energies between 8 and 8.5 Mev.* V. W. DESHPANDE, J. K. VERBA, AND H. W. FULBRIGHT, *University of Rochester.*—The reactions $Be^9(\alpha,n)C^{12}$ (ground state and first excited state) and $C^{13}(\alpha,n)O^{16}$ (ground state) have been studied in the energy range 8 to 8.5 Mev by use of millimicrosecond time-of-flight techniques. Excitation functions and angular distributions, with absolute cross sections, have been obtained. In the $Be^9(\alpha,n)C^{12}$ case the ground state neutron distribution is markedly different from the first excited state distribution. In both of these cases forward and backward peaking was found. Each distribution is generally similar to the corresponding distribution found earlier for alpha particles of 5 Mev.[1,2] The $C^{13}(\alpha,n)$ distributions are peaked forward and backward.

* Work supported by the U. S. Atomic Energy Commission.
[1] J. R. Risser, J. E. Price, and C. M. Class, Phys. Rev. **105**, 1288 (1957).
[2] J. P. Schiffer, Alfred A. Krauss, Jr., J. R. Risser, Phys. Rev. **105**, 1811 (1957).

S7. Cross Section and Angular Distributions of the (dn) Reaction in C^{12} near the 4-Mev Resonance.* J. W. VERBA, H. W. FULBRIGHT, AND V. K. DESHPANDE, *University of Rochester.*—The reaction $C^{12}(dn)N^{13}$ has been studied over a deuteron energy range from 3.80 Mev to 4.20 Mev in 50-kev steps. Angular distributions of neutrons leaving N^{13} in the ground state show a pronounced Butler peak at about 20° for all deuteron energies. The shapes of the (dn) angular distributions are similar to those of the protons from the $C^{12}(dp)N^{13}$ reaction for deuterons in the same energy region.[1] There are,

however, some differences in the excitation curves obtained at various angles. The absolute cross sections at the peaks are, in some cases, considerably larger than the corresponding (dp) cross sections. The peak (dn) cross sections vary from about 30 mb/sr at the resonance to about 15 mb/sr at 4.2 Mev. An attempt is made to analyze the data by assuming a small amount of compound nucleus formation interfering with stripping. The results are compared with corresponding results of the similar analysis of the (dp) data.[1]

* Work supported by the U. S. Atomic Energy Commission.
[1] T. W. Bonner, J. T. Eisinger, A. A. Kraus, and J. B. Marion, Phys. Rev. **101**, 209 (1956).

S8. Low Energy Neutrons from the (α,n) Reaction in Be^9.† F. A. St. Romain, J. Hanna, R. L. Bramblett, and T. W. Bonner, *Rice University.*—Experiments carried out on the detection of slow neutrons from the (α,n) reaction in Be^9 show a broad threshold beginning at an alpha particle energy of 4.3 Mev, and no detectable threshold for neutrons leaving C^{12} excited to the state at 7.656 Mev. Other experiments using the sphere-moderated neutron spectrometer[1] have measured the energies of these neutrons for $E_\alpha = 4.92$ and 5.11 Mev. The results indicate a peaking in the forward direction and an energy distribution consistent with their origin from inelastic alpha particle scattering leaving Be^9 excited to the level at 1.75 Mev, which subsequently breaks up with neutron emission. At an alpha particle energy of 5.11 Mev, the mean energy of these neutrons and the differential cross sections are: 0° (325 kev, 22 mb/sr); 70° (205 kev, 8 mb/sr); and 120° (65 kev, 2 mb/sr).

† Supported in part by the U. S. Atomic Energy Commission.
[1] R. L. Bramblett, R. I. Ewing, and T. W. Bonner, Nuclear Instr. and Methods **9**, 1 (1960).

S9. Neutron Groups from the Reaction $C^{14}(p,n)N^{14}$.† J. Hanna, T. W. Bonner, R. L. Bramblett, and F. A. St. Romain, *Rice University.*—The yield of neutrons from a thin target of C^{14} has been observed at 0° and at 90° to the bombarding beam in the energy range 2.8 to 5.4 Mev. Above 3.15 Mev the cross section for the two different groups of neutrons was obtained by use of the sphere-moderated neutron spectrometer.[1] Above 4.91 Mev a third group of neutrons was observed. Resonances in the reaction were obtained at proton energies of 2.89, 3.17, 3.36, 3.40, 3.61, 3.73, 3.89, 4.17, 4.22, 4.59, 4.92, 5.00, 5.13, and 5.24 Mev. No narrow resonances were obtained in the yield of neutrons leaving N^{14} in its first excited state that were not also observed for neutrons leaving N^{14} in its ground state. Resonances due to states in N^{15} with isotopic spin $T=\frac{3}{2}$ are expected for the n_1 group of neutrons but not for the n_0 group. The yield of n_1 neutrons shows some evidence for a broad level in N^{15} at an excitation of about 13.6 Mev which has isotopic spin $T=\frac{3}{2}$, but no narrow resonances were observed corresponding to states in C^{15} with excitations of 2.48 and 3.08 Mev.

† Supported in part by the U. S. Atomic Energy Commission.
[1] R. L. Bramblett, R. I. Ewing, and T. W. Bonner, Nuclear Instr. and Methods **9**, 1 (1960).

Saturday at 10:00

Auditorium 3 (C.M.)

(J. L. Tuck presiding)

Plasma I

T1. Measurement of Stark Profiles of Hydrogen and Helium Lines Emitted by Shock-Heated Plasmas in Electromagnetic T Tubes. H. F. Berg, A. Ali, R. Lincke, and H. R. Griem, *University of Maryland.**—The slab of plasma behind primary or reflected shock fronts served as thermal light source. Electron densities were determined from absolute continuum intensities. Temperatures in helium followed from intensity ratios of ion and neutral lines, or at lower temperatures and in hydrogen from relative line and continuum intensities. Line profiles were measured scanning with monochromators from shot to shot. (Intensities were reproducible within ±5%.) Experimental widths and shifts were compared with values calculated from measured electron densities and temperatures. For hydrogen ($H\alpha,\beta,\gamma$) the widths agree within 10% with theory,[1] for neutral helium (λ5875, 5006, 4713, 4471, 3889, 3188 A) within 15%.[3] Measured widths for ionized helium (λ 4686, 3203 A) agree within 10% with theory,[3] but λ 4686 A exhibits a blue shift (probably due to the quadrupole term in the quasi-static theory[4]). For neutral helium calculated[3] and measured shifts disagree by up to a factor of two in both directions.

* Sponsored by Geophysics Research Directorate of the Air Force and Office of Naval Research.
[1] H. R. Griem, A. C. Kolb, and K. Y. Shen, Phys. Rev. **116**, 4 (1959).
[2] H. R. Griem, M. Baranger, A. C. Kolb, and G. Oertel, (to be published).
[3] H. R. Griem and K. Y. Shen, Phys. Rev. (to be published).
[4] R. M. Herman, Bull. Am. Phys. Soc. **5**, 234 (1960).

T2. A Comparison between Langmuir Probe and Microwave Electron Density Measurements in an Arc-Heated Low-Density Supersonic Wind Tunnel.* L. Talbot, J. E. Katz,† and C. L. Brundin, *University of California, Berkeley.*—Measurements were made of the electron density in a low-density supersonic plasma jet flow by the stagnation point Langmuir Probe method.[1] The microwave interferometric methods developed by Wharton[2] were used on the same plasma jet. The two methods yielded results in reasonably good agreement. Therefore microwave means of measuring electron densities seem to provide a quick and reliable method for examining plasma jets, and in addition to electron density information it is possible to obtain information on the radial distribution of the ionized jet. An attempt to determine the electron temperature by measurement of the microwave power radiated from the jet was not successful. With improved techniques electron temperatures of plasma jets also may be measured quickly.

* Research sponsored by the U. S. Air Force Office of Scientific Research, Air Force and Development Command, and the U. S. Atomic Energy Commission.
† On loan from Lawrence Radiation Laboratory, Livermore.
[1] C. L. Brundin, L. Talbot, and F. S. Sherman, "Flow studies in an arc-heated low density supersonic wind tunnel," Univ. of Calif. Inst. of Eng. Research Rep. He-150-181 (April 15, 1960).
[2] C. B. Wharton, "Microwave diagnostics for controlled fusion research," Univ. of Calif. Radiation Lab. Rept. UCRL 4836 Rev. (September, 1957).

T3. Intensity Weakening of the Higher Members of the Balmer Series Observed in a Water Arc Plasma. S. Visvanathan, *General Electric Company, Philadelphia* (introduced by Wm. C. King).—One of the methods of estimating the temperature in a plasma is to measure the relative intensities of emission lines of a given species in the plasma. If the relative intensities for the various lines are plotted on a logarithmic

scale against their energies, one should obtain a straight line whose slope gives the temperature. Measurements[1] of the relative intensity of the Balmer lines in the water arc did not yield the above behavior. There was a progressive decline in intensity as one proceeded to higher members of the series. For the H_β and H_ϵ lines the reduction in intensity amounted to about 27% and 78%, respectively. If one assumes thermodynamic equilibrium in the arc plasma, the experimental results quoted above can be explained in terms of some aspects of the Stark effect of hydrogen lines, the high electric fields for the Stark effect arising from the large ion densities ($\sim 10^{17}$/cc) in these arcs. The two aspects of Stark effect considered are (1) the Stark broadening of the Balmer lines and the consequent merging of the consecutive members of the Balmer Series, (2) the field ionization of the electron from the upper levels of the hydrogen atom. These effects have been considered in connection with stellar spectra by A. Pannekoek.[2]

[1] H. Sadjian (private communication).
[2] A. Pannekoek, Monthly Notices Roy. Astron. Soc. 90, 694 (1938).

T4. Microwave Plasma Diagnostics. DEREK W. MAHAFFEY, *Boeing Scientific Research Laboratories.*—Extended measurements have been made of the theoretically predicted[1] and experimentally observed[2] shift in electron cyclotron resonance frequency, for a plasma in a magnetic field. The plasma parameters deduced from these measurements have been compared with those obtained using microwave interferometer and Langmuir probe techniques. The measurement of the shift in cyclotron frequency employs the "whistler" mode of of propagation to which even dense plasmas are transparent for low frequency microwave signals. The amount of the frequency shift should depend sensitively on β, the ratio of electron kinetic pressure to magnetic field pressure. Measurements of the shift corresponding to values for β in the range 10^{-5} to 10^{-6} have been made.

[1] J. E. Drummond, Phys. Rev. 112, 1460, (1958).
[2] D. W. Mahaffey, Bull. Am. Phys. Soc. 6, 389 (1961), this issue.

T5. On the Kinetic Equation for a Completely Ionized Gas. RALPH L. GUERNSEY, *Boeing Scientific Research Laboratories* (introduced by James E. Drummond).—The recent derivations[1-3] of the kinetic equation for a plasma are subject to a number of restrictions, notably the following: (1) sufficient time is supposed to have elapsed so that the higher distribution functions depend on time only through the one-particle distribution, and (2) the system is in the uniform state. The first assumption has been questioned by Fried and Wyld,[4] and the second clearly does not apply to problems such as that of plasma oscillations. A kinetic equation is derived which is valid for any state not too far from equilibrium, using the theory of singular integral equations. The terms which depend on time explicitly (i.e., not through f_1) are found to vanish asymptotically as $(\omega_p t)^{-1}$ for long times.

[1] R. Balescu, Phys. Fluids 3, 52 (1960).
[2] M. N. Rosenbluth and N. Rostoker, Phys. Fluids 3, 1 (1960).
[3] R. L. Guernsey, dissertation, University of Michigan, Ann Arbor, Michigan, July, 1960.
[4] B. D. Fried and H. W. Wyld, Jr., Space Technology Labs. Rept. No. STL/TR 60-0000-GR325.

T6. Equation of State of Gaseous Metallic Plasmas. D. S. VILLARS, *U. S. Naval Ordnance Test Station.*—An attempt has been made to implement a theory of H. S. Green which calculates the equation of state from correlation functions, $g_{ij}(r)$, giving the probability of finding a charged particle of type j in the immediate neighborhood of a point $\mathbf{x}_j$ when a charged particle of type i is at the point $\mathbf{x}_i$. These functions were to be approximated by successive iteration of an exponential equation involving a double integral. Calculations were programmed on the IBM 709 with the aid of FORTRAN language. Although results are obtainable in reasonable time for high temperatures of the order 10^6 °K, the calculations have been found not to converge at lower temperatures. Mathematical analysis shows that the integrand of the outer integral approaches a constant value as its variable s approaches infinity. A perturbation type of solution was next carried out which expands the correlation functions as power series in $\alpha = 2e(2\pi n/kT)^{-\frac{1}{2}}$. It was found that only even powers of alpha occur and that the inner integral is now integrable analytically. However, the calculations still do not converge.

T7. Attractive Two-Body Interactions in Plasmas. GILDA HARRIS, *Lawrence Radiation Laboratory, Livermore.*—It has recently been shown that in a classical plasma a shielded Coulomb (Yukawa) potential exactly describes the effective two-particle interactions. It therefore seemed reasonable to use this potential as an approximation to attractive two-particle quantum interactions in a sea of charged particles, such as a partially ionized hydrogen plasma. With this model there is no long range divergence, and the short range divergence can be eliminated by including a cutoff of the shielded Coulomb potential. Hydrogen-like single electron functions were used as a basis set with the effective nuclear charge as a variational parameter. The Debye shielding length was used in the potential. Bound-state energies were obtained as a function of the density and temperature of the system. The shielding displaces the energy levels toward higher energies. As the density is increased (or temperature decreased) the bound-state energies cross zero and there is a density-temperature line above which no bound states are possible.

T8. Properties of a Highly-Ionized Steady-State Deuterium Plasma. R. A. GIBBONS AND R. J. MACKIN, JR., *Oak Ridge National Laboratory.*—The generation and preliminary study of a highly-ionized steady-state deuterium plasma in a magnetic field has been reported previously.[1,2] Further studies have shown: the mean random energy of the ions was about 24 ev, independent of the ion mass and charge; the mean energy of the electrons was of the order of 100 ev; the electron and ion densities were about 10^{14} cm^{-3}; the plasma was 99% ionized; deuterium and hydrogen ions constituted >99.9% of the total ion density; and the ratio of electron to ion drift velocities is about 3. The use of Spitzer's equations[3] for the various energy exchange times of electrons and ions suggests: all ions were in equilibrium at the same temperature; the electrons were in equilibrium with themselves; and the electrons were heating the ions as they drifted through the plasma. Supplementary data will be presented.

[1] R. J. Mackin, Jr. and R. A. Gibbons, Bull. Am. Phys. Soc. 5, 370 (1960).
[2] R. A. Gibbons and R. J. Mackin, Jr., Bull. Am. Phys. Soc. 5, 370 (1960).
[3] L. Spitzer, Jr., *Physics of Fully Ionized Gases* (Interscience Publishers, Inc., New York, 1956).

T9. Fokker-Planck Coefficients for a Plasma Including Cyclotron Radiation. ALBERT SIMON, *Oak Ridge National Laboratory,** AND NORMAN ROSTOKER, *General Atomic.*—The exact coupled equations for the pair correlation functions resulting from a first order expansion of the Liouville equation have been derived previously.[1] The time-asymptotic solution of these equations constitute the Fokker-Planck coefficients for plasma and radiation. Exact solutions of these equations have been derived previously for the case of an infinite plasma with no magnetic field present[2] and for the case of a constant magnetic field with no radiation coupling.[3] We are now attempting to solve the problem with both a magnetic field and radiation coupling. The result will immediately yield a general formula for cyclotron radiation from a plasma. We have succeeded in reducing the problem to a non-integral

equation similar to that of Lenard. One must still solve for the imaginary part of H and corresponding functions. If one conjectures that the imaginary part is zero, we obtain an explicit formula for cyclotron radiation which is at considerable variance with current theories. The problem is also being attacked by a generalization of the superposition method.

* Operated by Union Carbide Corporation for the U. S. Atomic Energy Commission.
[1] A. Simon and E. G. Harris, Phys. Fluids **3**, 245 (1960).
[2] A. Simon, Phys. Fluids, **4**, 586 (1961).
[3] N. Rostoker, Phys. Fluids **3**, 922 (1960).

T10. Time Lag in the Thermalization of a Fast Ion in a Plasma. H. L. FRISCH, *Bell Telephone Laboratories, Inc.* (introduced by N. B. Hannay).—The time lag in the thermalization of the spherical mean speed of a fast ion injected into a plasma is defined and computed without solving the Fokker-Planck equation governing the distribution in speed. The time lag and certain related, recursively computable, time moments can serve as local measures of the rate of evolution of the Maxwellian distribution from an initial one, particularly for large values of the speed. Numerical computations of the time lag are presented for a fully ionized deuterium plasma for two initial conditions. Certain natural extensions of the time lag are briefly mentioned.

T11. Steady-State Shielding Response of an Irradiated Plasma. JEAN I. F. KING, *Geophysics Corporation of America.*—For a fairly broad range of certain nondimensional parameters it is possible to couple rf power incident on an inhomogeneous plasma, with the resultant beam attenuation appearing as ohmic heating of the medium. The plasma reacts to this heating with a local rise in temperature and electron density, which in turn alters the pattern of heat deposition. In general, the plasma responds by becoming increasingly reflecting, with the heating zone moving towards the radiation source. A closed-form solution for the steady-state plasma response has been obtained and the shield shape and velocity calculated in terms of basic plasma parameters.

T12. Ion Wave Instability at a Sheath.* FRANCIS F. CHEN, *Princeton University.*—The so-called Bohm criterion for the formation of a stable sheath has been examined in detail and found to be essentially correct. In fact, the requirement on the ion velocity at the sheath edge is even more stringent: it must be essentially equal to $(kT_e/M)^{\frac{1}{2}}$ rather than equal to or greater than this. If this velocity were imparted by steady electric fields in the plasma, the resultant ion stream would be unstable, according to the theory of Bernstein and Kulsrud. Thus, it may be possible to excite the instability merely by inserting a large electrode into a plasma in which $kT_e \gg kT_i$. The instability would grow until it is Landau-damped by the spread in ion energies acquired from the ion waves. Waves propagating backward into the plasma would be Doppler-shifted and appear as very low frequency oscillations in the laboratory. Whether or not this actually will happen is difficult to determine theoretically; however, experimental evidence for it will be given. If this hypothesis were correct it would be futile to try to excite and detect ion waves in a plasma with end plates, since the system would be full of ion oscillations to begin with.

* Research performed under the auspices of the U. S. Atomic Energy Commission.

T13. Transients in the Formation of a Current Sheath at a Plasma Boundary.* LESTER KRAUS, *Republic Aviation Corporation.*—The formation of a conducting sheath at a plasma boundary due to a strong electromagnetic field is analyzed. The case where the plasma properties do not change was treated previously.[1] Here a simple model of a plasma is used in which the effects of the field on the plasma is taken into account and divided into electron heating, ionization, and ion heating.[2,3] Each of these phases is treated separately and the problems are reduced to nonlinear diffusion-like equations. Analytic and numerical solutions then provide a time history of the growth of the current sheath and the associated magnetic field. Conditions will be discussed which determine whether the sheath will eventually become a steady state discharge or a dynamic pinch.

* Supported in part by the U. S. Air Force Office of Scientific Research.
[1] J. L. Neuringer, L. Kraus, and H. Malamud, Bull. Am. Phys. Soc. 6, 309 (1961)
[2] K. Watson and J. Wyld, Conference on Thermonuclear Reactions, Gatlinburg, Tennessee, 1956.
[3] J. Killeen, G. Gibson, and S. A. Colgate, Phys. Fluids **3**, 387 (1960).

T14. Behavior of a Thermionic Plasma Converter with a $(UC)_{0.3}(ZrC)_{0.7}$ Emitter.* W. A. RANKEN AND E. T. TEATUM, *Los Alamos Scientific Laboratory.*—A cesium plasma cell, having a $(UC)_{0.3}(ZrC)_{0.7}$ emitter incorporated into a plane parallel geometry, has been constructed and tested. The collector of this cell has an area approximately 10% that of the emitter and is surrounded by an annular guard ring. Measurements which have been made include the determination of the dependence of short circuit current, open circuit voltage, and positive ion current on cesium vapor pressure and emitter temperature. The data give evidence that for a cesium vapor pressure on the order of 2×10^{-3} mm Hg and for emitter temperatures above 2200°K, the mode of ion formation changes abruptly from an effect best described by the modified Saha equation and characterized by fractional ionization values of less than 10%, to an effect characterized by fractional ionization values on the order of 50% to 100%, with apparent electron temperatures on the order of 6500°K.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

SATURDAY AT 10:00

Auditorium 4 (C.M.)

(F. M. MEDINA presiding)

Theoretical Physics III

U1. Integrated Cross Section for a Velocity-Dependent Potential.* O. ROJO† AND J. S. LEVINGER, *Louisiana State University.*—For a possible distinction between a velocity-dependent two-nucleon potential,[1] and a static potential with an infinite repulsive core,[2] we study their contributions to σ_{int} for the deuteron photoeffect. Both potentials considered are central, with square shapes, and have Serber mixtures for the attractive parts. (They have Wigner character for the repulsive core, and for the velocity-dependent term, respectively.) By using Razavy's notation[1] for the velocity-dependent potential, $b=2f$, $\lambda=-0.25$, and $V_0=37.5$ Mev. For the static potential, $b=1.84f$, $c=0.24f$, and $V_0=41.5$ Mev. These potentials are adjusted to give (1) the observed binding energy of the deuteron; (2) the same mean square

radius of 155 mb and (3) the same value (260 Mev) at which the ^3S phase shift changes sign. By using sum-rule calculations, in the electric-dipole approximation, we find that σ_{int} for the static case is 38.0 Mev-mb, while for the velocity-dependent case it is very nearly the same, namely, 38.8 Mev-mb.

* Supported in part by the National Science Foundation.
† Creole Foundation Fellow, now at U.C.V., Caracas, Venezuela.
[1] M. A. Razavy and J. S. Levinger, Bull. Am. Phys. Soc. 5, 441 (1960).
[2] Gomes, Walecka, and Weisskopf, Ann. Phys. 3, 241 (1958).

U2. Vector Mesons and Nuclear Forces. W. K. R. WATSON,* *University of Southern California.*—Recently Gell-Mann[1] has suggested a theory of vector mesons, two of which can be used to give a semi-quantitative explanation of the work of Hofstadter and Herman[2] in their investigations of nuclear electromagnetic form factors. Following the original suggestion of Teller, two of these vector mesons (ρ_0 and ω_0) have been incorporated in the description of *p-p* and *n-n* scattering at 140 Mev and 300 Mev, respectively. The one pion and photon contributions are included as well as the approximate form factor variations. The *p-p* scattering predictions agree well with experiments (to within 10%), whereas the *n-n* calculation gives a differential cross section in disagrcement from 0–30°, but within experimental error elsewhere.

* Consultant, California Institute of Technology (J.P.L.), Pasadena, where part of this work was performed.
[1] M. Gell-Mann, Phys. Rev. (to be published).
[2] R. Hofstadter and R. Herman, Phys. Rev. Letters 6, 293 (1961).

U3. Binding Energy and Size of the He^4 Nucleus.* VICTOR FLORES-MALDONADO, *Instituto Politécnico Nacional y Universidad Nacional de México.*—Theoretical calculations of the binding energy of the He^4 nucleus with the assumption of reasonable central potentials without core give results that are too high when compared with the experimental value. When tensor potentials of adjustable range are added, the theoretical binding energy is lowered, but the experimental size of He^4 nucleus remains unexplained. The binding energy is found by calculation of the expectation value of the Hamiltonian, but the parameter of the wave functions considered is here adjusted so as to reproduce the root mean square radius obtained from electron-He^4 scattering experiments. The correct binding energy is found; this seems to indicate that the method of obtaining the wave function from the experimental density distribution is very effective.

* This work was performed at Cornell University as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

U4. Calculation of Two-Particle Energy Levels with the Help of Transformation Brackets. T. A. BRODY AND A. MONDRAGÓN B., *Institute of Physics, National University of Mexico.*—The tabulation of transformation brackets for harmonic oscillator wave functions in the nuclear shell model (Brody and Moshinsky[1] and references given there) makes it possible to calculate the matrix elements of spin-orbit coupling and tensor forces, both of Wigner and exchange type, whatever the radial dependence is chosen to be. The method is immediately applicable to nuclei with two particles outside a closed shell, such as Ca^{42} or with two holes in a shell, such as Pb^{208}. Various types of forces are considered; in each case the Talmi integrals arising are left as parameters and fitted from the experimental data. The resulting values are considered from the point of view of their reasonableness within the framework of nuclear-shell theory.

[1] T. A. Brody and M. Moshinsky, *Tables of Transformation Brackets* (Monografías del Instituto de Física, UNAM, México, 1960).

U5. Optical Model with Pauli Principle. A. MONDRAGÓN B., *Instituto de Física, Universidad Nacional de México.*—An appropriate formalism to the study of the optical model of nuclear reactions is presented, in which the identity of all nucleons is fully taken into account. We start from an independent-particle model, so as to preserve the symmetry of all nucleons; taking as perturbations all residual interactions. The optical potential is then expressed in terms of a perturbation series in powers of the two-body interactions. In this way the parameters of the optical potential can be related to nucleon-nucleon forces, making it possible to give a criterion for the validity of the model. The first two terms of this expansion are examined and approximate expressions for the real and imaginary parts of the optical potential are given.

U6. Application of Many Parameter Functions Which Arise in Optical Model Problems. ALEX E. S. GREEN, *Convair, San Diego.*—The application of optical model phenomenological theory to extensive nuclear scattering and bound state data takes one into a multiparameter space spanning six or seven dimensions. When data fitting must be accomplished in the presence of so many adjustable parameters the decision making process to obtain the best fits becomes extremely complex and to a great extent personal judgment or even personal taste comes into play. In an effort to arrive at objective best fits a hunting procedure related to the method of steepest descent has been examined. Illustration of the techniques involved and the conclusions as to parameter interrelationships will be given. Since the functional forms and data fitting techniques utilized in optical model studies involve very complex consideration and multidimensional parameter spaces, these same techniques have application to a very broad class of problem. As an illuminating example of the utilization of optical model functional forms and fitting techniques, we will consider one of considerable interest to physicists, namely to compensation schedules.

U7. Shell Model Study of Ground State and First Two Excited States of Mn^{55}.* ERVIN H. SCHWARCZ, *Lawrence Radiation Laboratory, Livermore.*—A shell model calculation for Mn^{55} was carried out to see if the inclusion of neutron-proton interactions would correctly predict the spin of the ground state and first two excited states for reasonable values of the range parameter. It is assumed that the last 5 protons are in the $1f_{7/2}$ shell while the last 2 neutrons may be in either the $^3p_{3/2}$ or the $1f_{5/2}$ shell. A Gaussian interaction is used for the proton-proton, neutron-neutron and neutron-proton interactions. A Serber mixture and a mixture with 20% Bartlett force were tried. Since there is some uncertainty about the $1f_{5/2}-2p_{3/2}$ single particle level spacing, 3 different values of this separation were used. All possible spins J_1 for 5 protons were coupled to all possible spins J_2 for 2 neutrons to obtain the final spin of the nucleus for each of the 3 levels and the resulting matrices diagonalized on a digital computer. It will be shown that the correct order of the levels can be obtained for many values of the range parameter.

* Work performed under auspices of the U. S. Atomic Energy Commission.

U8. Nuclear Photoeffect below the Giant Resonance, Particularly Be^9 and C^{13} Angular Distribution and Polarization. EUGENE GUTH, *Oak Ridge National Laboratory,* AND N. C. FRANCIS AND D. T. GOLDMAN, *Knolls Atomic Power Laboratory.*—By using cluster model of Be^9 ($=Be^8+$neutron) in 1948 first distorted-wave-direct-interaction theory was developed just before emergence of shell model. Good agreement with experiment was obtained by postulating electric dipole transitions coupled with existence of resonance with S level a little below or above threshold and (somewhat broader) resonance with D level above 2.8 Mev (Be^9 ground state: P). Puzzles: (1) Postulated S and D levels had not been found experimentally; (2) Be^9 level was found at 2.43 Mev. This level did *not* show up in $\sigma(\gamma,n)$. Later measurements, first by Moak, Good, and Kunz, did show levels at 1.8, 3.2, and 4.8 Mev, in addition to the level at 2.43. Most recently, puzzle (2) has apparently been solved by Jakobson.

He found, around 3 Mev, an angular distribution compatible with a D level and a small peak at 2.43 Mev, probably assignable to magnetic dipole transition. An improved version of the theory, published by the present authors (before hearing of Jakobson's work) predicted, among other things, quantitatively the rise of $\sigma(\gamma,n)$ at the threshold, which has been subsequently found at Notre Dame. Angular distribution and polarization have been computed and will be presented.

U9. On the Theory of (n,γ) Reactions. L. ESTRADA, *Instituto de Física, Mexico.*—The radiative neutron capture is discussed considering a scattering system in interaction with a radiation field. The scattering system for the neutron is assumed to be a very simple model consisting of only two possible channels. The direct and resonant processes are exhibited and the competition between these radiative processes and the elastic scattering is discussed. Finally, some relations with the γ,n) process are pointed out.

U10. Effects of Target Spin on Fission Anisotropy.* R. B. LEACHMAN AND E. E. SANMANN, *University of California, Los Alamos.*—The measured anisotropy of fragments from (n,f) fission increases with the spin I_0 of the target nucleus, contrary to qualitative expectations from the Bohr theory.[1] To investigate the effects of target spin on anisotropy, we have carried the distribution in M through the Bohr theory, in which distributions $F(K) \propto \exp(-K^2/2K_0^2)$ and $G(L) \propto L$ up to a maximum L_m were used. Here, the neutron angular momentum is L and the projections of the total spin $I=I_0+L$ are K on the nuclear symmetry axis and M along the neutron beam. In expanded form the anisotropy obtained is $W(0°)/W(90°) = 1+(L_m^2/8K_0^2)+(L_m^4/288K_0^4)-(L_m^2I_0^2/72K_0^4)$, where the last term, which is not of leading order, is the effect expected by Bohr. However, this term is compensated by the additive anisotropy term $I_0^2\delta/10K_0^2$ resulting from the use of a nuclear deformation δ in the theory, where $\delta \approx 0.25$. The remaining increase of anisotropy with target spin for agreement with measurements can be obtained by the similar use of an assumed fissionability $\Gamma_f/\Gamma_n = p\exp(I^2/A^2)$ dependence on I. The additive anisotropy term obtained is

$$(1+p)^{-1}[(L_m^4/48A^2K_0^2)+(L_m^2I_0^2/6A^2K_0^2)].$$

* Work supported by the U. S. Atomic Energy Commission.

[1] Bohr, *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* (United Nations, New York, 1956), Vol. 2, p. 151.

U11. Primordial Nuclei. GERTRUDE TIRING SCHWARZMANN.—The universe starts with the creation of gigantic numbers of light-wave-pairs, *each* pair forerunner and having the quantity of inertia of a galaxy; its light waves, revolving in opposite senses about a common vacant center, decompose into gigantic numbers of light waves, decomposing in turn into proton or electron pairs.[1] Formation of antineutrons prevents redematerialization of equal numbers of proton and electron pairs.[1] Each primordial nucleus, consisting of gigantic numbers of formations, numbering from one to immense numbers of alphas, explodes by multiple fission. Instantaneous spontaneous fissions of generations and generations of fission products follow, causing explosive expansion of the stationary proto-galaxies. When fissions no longer are instantaneous the heavy nuclei, as did the light ones since they existed, capture their extranuclear satellites. Gravitation causes contraction of the stationary galaxies. Contraction stops in the near past and slight expansion of the stationary galaxies becomes observable. With telescopes, reaching into the most distant past, tremendous blue-shifts of the spectral lines from stationary exploding proto-galaxies should be discovered.

[1] See Nuclear Structure in this issue.

SATURDAY AT 10:00

Auditorium 7 in "B" Building (C.M.)

(C. H. TOWNES presiding)

Invited Papers

UA1. Confirmation of the Gravitational Red Shift. R. V. POUND, *Harvard University.* (40 min.)

UA2. Origin of the Moon and the Solar System. H. C. UREY, *University of California, La Jolla.* (40 min.)

UA3. Space-Science Activities in the United States Space Programme. H. L. DRYDEN, *National Aeronautics and Space Administration.* (40 min.)

SATURDAY AT 10:00

Auditorium 5

(W. B. NOTTINGHAM presiding)

Division of Electron Physics

Symposium on Particle Impact Phenomena

V1. Field-Ion Microscopy. E. W. MUELLER, *Pennsylvania State University.* (30 min.)

V2. Atom Ejection Patterns in Single-Crystal Sputtering. G. K. WEHNER, *General Mills, Inc.* (20 min.)

V3. Calculations of Impact Phenomena in Lattices. G. H. VINEYARD, *Brookhaven National Laboratory.* (30 min.)

Invited Paper on General Programme

V4. Title and speaker to be announced.

SATURDAY AT 10:00

Auditorium 2 (C.M.)

(FREDERICK SEITZ presiding)

Invited Papers in Solid-State Physics I

VA1. Electric Breakdown in the Solid State. ALONSO FERNÁNDEZ, *Universidad Nacional Autonoma de México.* (30 min.)

VA2. Mössbauer Effect and Hyperfine Interactions in Magnetic Materials. S. S. HANNA, *Argonne National Laboratory.* (30 min.)

VA3. Nuclear Spin Relaxation and Impurities in Metals. L. C. HEBEL, *Bell Telephone Laboratories.* (30 min.)

VA4. Equation of State of Metals under High Pressures. F. D. PIRETO, *Universidad Nacional Autonoma de México.* (30 min.)

VA5. Study of Lattice Vibrations by Neutron Diffraction. JOHN YARNELL, *Los Alamos Scientific Laboratory.* (30 min.)

SATURDAY AT 14:30

Auditorium 7 in "B" Building (C.M.)

(A. FERNANDEZ presiding)

Invited Papers in Solid-State Physics II

W1. Electron-Spin-Resonance Experiments on Shallow Impurities in Silicon and Germanium Subjected to Uniaxial Stresses. GEORGE FEHER, *University of California, La Jolla.* (30 min.)

W2. Band Parameters from Cyclotron-Resonance Experiments in Uniaxially Stressed Silicon. J. C. HENSEL, *Bell Telephone Laboratories.* (30 min.)

W3. Study of Anisotropic Defects by Stress-Induced Alignment. J. W. CORBETT, *General Electric Research Laboratory.* (30 min.)

W4. Strain Effect on Optical Spectra of Transition Elements in Ionic Crystals. S. SUGANO, *Bell Telephone Laboratories.* (30 min.)

SATURDAY AT 14:30

Auditorium 2 (C.M.)

(E. W. MUELLER presiding)

Invited Papers of the Division of Electron Physics

Atomic Collisions

WA1. Recent Advances in Theoretical Aspects of Atomic Collisions. LARRY SPRUCH, *New York University.* (40 min.)

WA2. Recent Advances in Experimental Aspects of Atomic Collisions. B. BEDERSON, *New York University.* (40 min.)

SATURDAY AT 14:30

Auditorium 6 (C.M.)

(H. W. FULBRIGHT presiding)

Neutron Physics II; Fission

X1. Total Neutron Cross Section of O^{18}.* F. J. VAUGHN, H. A. GRENCH, W. L. IMHOF, J. H. ROWLAND, AND M. WALT, *Lockheed Missiles and Space Division.*—The total neutron cross section of O^{18} has been measured from 400 kev to 2.5 Mev and at 8.5, 9.5, 10.5 and 11.5 Mev by a transmission experiment. The neutrons were produced using the $Li^7(p,n)Be^7$, the $T(p,n)He^3$, the $C^{14}(d,n)N^{15}$, and the $N^{15}(d,n)O^{16}$ reactions in the appropriate energy intervals. Protons or deuterons were obtained from a 3.5-Mev Van de Graaff accelerator. The scattering samples consisted of thin-

walled stainless steel cylinders 1- and 2-cm long containing water enriched to 97% in O^{18}. The known hydrogen cross section was subtracted to obtain the O^{18} total cross section. The neutrons were counted with a plastic phosphor and time-of-flight techniques. Prominent resonances were observed at neutron energies of 0.70, 1.20, 1.26, 1.84, and 2.45 Mev, and a broad maximum was found centered at 1.5 Mev. The measurements will be extended down to 120 kev and into the energy region from 2.5 to 8.5 Mev.

* Supported jointly by the Lockheed General Research Program and the U. S. Atomic Energy Commission.

X2. Neutrons from the 31.5-Mev Proton Bombardment of Beryllium-9, Nitrogen-14, and Aluminum-27. H. E. ADELSON* AND C. N. WADDELL,† *Lawrence Radiation Laboratory, Berkeley.*—The energy spectra and absolute differential cross sections of neutrons of energy greater than 5 Mev emitted from thin targets of beryllium, nitrogen (melamine), and aluminum bombarded by 31.5-Mev protons were measured at three angles (50°, 90°, and 127°) at the Berkeley linear accelerator. The 4-in. hydrogen bubble chamber was used as a neutron spectrometer.[1] The energy spectra from the beryllium and nitrogen bombardments contained structure that may correspond to levels in the residual nuclei of the $Be^9(p,n)B^9$ and $N^{14}(p,n)O^{14}$ reactions. Poor statistics did not permit definite level assignments, but several of the possible levels of B^9 correspond to known levels of its mirror nucleus, Be^9. The angular dependence of the neutron production above 5 Mev from all three targets shows a forward asymmetry. The production from aluminum was in a ratio of 5:3:2 for 53°, 90°, and 127° (lab), respectively.

* Present address: Space Physics Laboratory, Convair-Astronautics, San Diego, California.
† Present address: University of Southern California.
[1] H. E. Adelson, H. A. Bostick, B. J. Moyer, and C. N. Waddell, Rev. Sci. Instr. 31, 1 (1960).

X3. Absolute Cross Section for the $P^{31}(n,\alpha)Al^{28}$ Reaction.* FLETCHER GABBARD AND W. C. LOOMIS, *University of Kentucky.*—The cross section for the $P^{31}(n,\alpha)Al^{28}$ reaction has been measured for the neutron energy range from 12.6 to 16.5 Mev using the radioactivation technique. The neutron flux from the $T(d,n)He^4$ source was measured with a $1\frac{1}{2}$ in. $\times 1\frac{1}{2}$ in. plastic scintillator. The neutron detector efficiency was measured by the alpha-particle recoil method. The efficiency at a neutron energy of 14.7 ± 0.2 Mev is 10.7 $\pm 0.5\%$ for a bias setting of 20% of the average-maximum proton pulse height. The activity produced in the ZnP samples was counted in a 3 in. $\times$ 3 in. NaI(Tl) scintillation spectrometer. Preliminary results for the $P^{31}(n,\alpha)Al^{28}$ cross section give 98 ± 12 mb at a neutron energy of 14.1 Mev. Data at other energies and the details of the neutron detector calibration will be given.

* Partially supported by the U. S. Atomic Energy Commission.

X4. $Ta^{181}(p,n)W^{181}$, $Pt^{195}(p,n)Au^{195}$, and $Au^{197}(p,n)Hg^{197}$ Excitation Functions between 4 and 13 Mev.* L. F. HANSEN, R. C. JOPSON, HANS MARK,† AND C. D. SWIFT, *Lawrence Radiation Laboratory, Livermore.*—The excitation functions for $Ta^{181}(p,n)W^{181}$, $Pt^{195}(p,n)Au^{195}$ and $Au^{197}(p,n)Hg^{197}$ reactions have been measured from 4- to 13-Mev bombarding energies. The stacked foil technique was used. The activity of the residual nucleus was measured by counting the x rays coming from electron capture or isomeric transitions. Absolute value of the cross sections were obtained for Ta^{181} and Au^{197}, by normalizing their excitation functions to the (p,n) cross sections below 7 Mev, given by the long counter technique. The total experimental reaction cross section for Ta^{181} and Au^{197} between 7 and 13 Mev are compared with the optical model calculations of Bjorklund and Fernbach.[1] Threshold and values for $(p,2n)$ for Ta^{181} and Au^{197} are also given.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
† Department of Physics, M.I.T., Cambridge, Massachusetts.
[1] Private communication.

X5. Compound-Elastic Scattering of Fast Neutrons in Lead.* P. L. OKHUYSEN, J. D. BRANDENBERGER, AND W. R. SMITH, *The University of Texas.*—Calculations have been performed of the differential compound-elastic scattering of fast neutrons by lead isotopes using the Hauser-Feshbach[1] theory. These angular distributions exhibit symmetry about 90° with large forward and backward peaking. The peak-to-valley ratio is as large as four. Previous measurements[2] show 90° symmetry but no peaking. More precise measurements have been made using an improved time-of-flight spectrometer and lead scatterers having a preponderance of the 208 and 206 isotopes, respectively. The peaking has been observed and found to agree, within experimental error, with the theoretical predictions. The experimental and theoretical results will be presented and the comparison of the two will be discussed.

* Work supported in part by the U. S. Atomic Energy Commission and The University of Texas Research Institute.
[1] W. Hauser and H. Feshbach, Phys. Rev. 87, 366 (1952).
[2] P. L. Okhuysen and J. T. Prud'homme, Phys. Rev. 116, 986 (1959).

X6. Neutron Background in the Bremsstrahlung Beam of a 22-Mev Betatron.* RONALD I. EWING, *Sandia Laboratory,* R. L. BRAMBLETT, *Lawrence Radiation Laboratory,* AND T. W. BONNER, *Rice University.*—The most probable energy of the "background" neutrons produced principally in the lead collimation of a 22-Mev betatron during its operation was found to be 0.9 ± 0.1 Mev. Neutron detectors consisting of rhodium foils mounted inside paraffin spheres of various diameters were irradiated at a point 108 cm from the platinum electron target on the axis of the bremsstrahlung beam, and the activity of the 44-sec beta decay of Rh^{104}, which follows thermal neutron capture in Rh^{103}, was counted. A lead plug placed in the beam exit port reduced the bremsstahlung intensity and increased the neutron intensity without appreciable distortion of the neutron spectrum. The detectors were calibrated using monoenergetic neutrons produced with a Van de Graaff accelerator. The response of the detectors to the "background" spectrum is fitted by the following group of monoenergetic neutron fluxes.

Neutron energy (Mev)	2.0	1.0	0.27
Flux (10^6n/cm^2-r)	2.2	32.0	3.1

An epithermal flux of 4.8×10^2 was also detected.

* Supported by the U. S. Atomic Energy Commission and the University of Texas, and M. D. Anderson Hospital and Tumor Institute.

X7. Space-Dependent Neutron Thermalization. P. F. ZWEIFEL, R. K. OSBORN, AND G. GYOREY, *University of Michigan.*—Hurwitz *et al.*[1] showed that the gas cross section for neutron thermalization can be expanded in powers of the inverse moderator mass and for infinite media the integral transport equation reduces in first approximation to a second order differential equation, a result obtained by Wilkins in a different manner. This result adapts to finite systems by adding $\nabla\cdot\mathbf{J}$ to the original equation in p_1 approximation. The usual Fick's rule is modified however, and the resultant equations do not involve solely the addition of a leakage term $(-D\nabla^2\Phi)$ to the infinite medium equation. Instead, one obtains a fourth order equation with mixed space-energy derivatives. In momentum space, the coefficients of the zeroth and first energy derivatives include terms proportional to ϵ^{-1} the proportionality factor being $\mu\sigma_0 D_0^2 k^2[2\sigma_t(1+D_0^2k^2)]^{-1}$

for the zeroth term and twice that for the first term. Also the absorption cross-section is multiplied by $(1+L^2k^2)(1+D^2k^2)^{-1}$. The notation is that of reference 1 except σ_0 is the free atom cross section; $D_0=(3\sigma_t)^{-1}$, $D=D_0(1-\mu\sigma_0/2\epsilon\sigma_t)$ and $L^2=D/\sigma_a$. Also, the source is multiplied by $(1+D^2k^2)^{-1}$. Numerical solutions will be presented.

[1] Hurwitz, Nelkin, and Habetler, Nuclear Sci. and Engr. 1, 280 (1956).

X8. Moments Calculations of the Age in a Generalized Mixture of Moderators and Metals.* G. D. JOANOU, A. J. GOODJOHN, AND N. F. WIKNER, *General Atomic.*—Exact calculations of the age in a generalized mixture of moderators and metals have been performed by computing the first few moments of the slowing down distribution.[1] The treatment of the energy degradation of neutrons takes into account the anisotropy of the elastic scattering to sixth order in a Legendre expansion using data not previously available.[2] Energy degradation through inelastic and n, $2n$ processes are included, and various models for handling these events are evaluated. For the simple moderators, H_2O, D_2O, Be, BeO, and C, we have calculated the age to indium resonance to be 26.1 cm², 113.0 cm², 78.0 cm², 95.0 cm², and 310 cm², respectively. An unweighted average of several experiments gives 27.2±0.5 cm², 110 (99.8% D_2O) cm², 80±2 cm², 93.5±5 cm², and 311±5 cm² for these materials. In addition to fission sources, results have been obtained for monoenergetic, RaBe and PoBe neutron sources for these simple moderators and mixtures of these moderators and metals. The energy dependent neutron cross sections employed will be discussed; among other things, these calculations serve as good integral checks of these data.

* This work was supported by the U. S. Atomic Energy Commission.
[1] R. E. Marshak, Revs. Modern Phys. 19, 185 (1947).
[2] R. O. Lane, *et al.*, Ann. Phys. 12, 135 (1961).

X9. Dependence of Fission Symmetry on Angular Momentum.* G. P. FORD AND R. B. LEACHMAN, *Los Alamos Scientific Laboratory.*—The Pd^{109}, Pd^{112}, Ag^{111}, and Ag^{113} symmetric yields Y_s and the Zr^{97} and Ba^{139} asymmetric yields Y_a from both $n+U^{235}$ and $\alpha+Th^{232}$ fissions have been radiochemically measured over a 15- to 25-Mev span of U^{236} excitation energies. For both cases the ratio Y_s/Y_a increased exponentially with energy, but with a 34±10% decreasing step at 21-Mev excitation, corresponding to the onsets of $(\alpha,2nf)$ and $(n,2n'f)$ fissions. Above 20-Mev excitation, the ratios Y_s/Y_a of Pd^{109}, Pd^{112}, Ag^{111}, or Ag^{113} yields to Zr^{97} yields were 23±14% greater for $\alpha+Th^{232}$ than for $n+U^{235}$ at the same excitation energies; results were similar for ratios to Ba^{139} yields. There exists the unlikely possibility of the effect having been due to an approximately 23% loss of both zirconium and barium from the thorium solutions; silver and palladium were known not to have been lost from the uranium solutions. A more plausible explanation is an angular momentum (I) effect in fission. If the moment of inertia g_a for asymmetric fission is smaller than the symmetric g_s, then the results are in qualitative agreement with the statistical model relation

$$Y_s/Y_a=\exp[\hbar^2I^2(g_a^{-1}-g_s^{-1})/2T].$$

X10. Measurement of Mass and Energy of Fragments from Spontaneous Fission of Cf^{252} Using Solid-State Detectors.* W. M. GIBSON, *Bell Telephone Laboratories*, AND T. D. THOMAS AND G. L. MILLER, *Brookhaven National Laboratory.*—By using p-n junction solid-state detectors, we have determined the mass and energy spectra of the fragments formed in the spontaneous fission of Cf^{252}. Two detectors with the fission source between them were used to measure the energies of the two coincident fragments. The number of events corresponding to a particular pair of energies was stored in a 64- × 64-channel two-dimensional pulse-height analyzer. The data have been analyzed to give the total mass and energy spectra, the mass spectrum for a given energy, the energy spectrum for a given mass ratio and the energy spectra of the light and heavy fragments separately. The results are in general agreement with the time-of-flight data of Milton and Fraser.[1] The curves of mass yield for a given total energy show two narrow peaks corresponding to nearly symmetric fission for the highest energies and two broad peaks corresponding to very asymmetric fission at lower energies. There is some filling in of the symmetric valley at the lowest energies. These features are examined in terms of the mass surface and what is known about charge distribution in fission.

* Research performed in part under the auspices of the U. S. Atomic Energy Commission.
[1] J. C. D. Milton and J. S. Fraser, Phys. Rev. 110, 476 (1958).

X11. Time-of-Flight Measurements of Charged-Particle-Induced Fission.* S. L. WHETSTONE, JR., AND R. B. LEACHMAN, *Los Alamos Scientific Laboratory.*—Binary fission of Th^{232} and U^{233} induced by alpha particles has been studied by coincident time-of-flight measurements of the velocities of fragments emitted at 90° to the beam direction. The velocity data were converted to distributions in the primary masses and in the kinetic energies. At 21.6-, 25.3-, and 29.1-Mev alpha energy, the peak-to-valley yield ratios were, respectively, 6.6, 4.2, and 2.9 for Th^{232} fission and 3.9, 1.9, and 1.6 for U^{233}. Although the mass resolution estimated from the measured timing uncertainties (and confirmed by satisfactory agreement with radiochemical peak-to-valley yields) would resolve a reported peak[1] in the yield distribution at symmetric masses, none was observed. The measurements, which include a large number of symmetric mass events, establish a dip in the average total fragment kinetic energy E_k at symmetry of 9–12 Mev for Th^{232} and 6–8 Mev for U^{233}. Maximum E_k occur for mass ratios of 1.30 and 1.28, which are lower ratios than the most probable fission modes.

* Work supported by U. S. Atomic Energy Commission.
[1] L. J. Colby, M. L. Shoaf, and J. W. Cobble, Phys. Rev. 121, 1415 (1961).

SATURDAY AT 14:30

Auditorium 5

(Chairman to be chosen)

Post-Deadline Papers, If Any

SATURDAY AT 14:30

Auditorium 4 (C.M.)

(PETER HAVAS presiding)

Theoretical Physics IV

Y1. Elementary Particles and the Seniority Concept. I. RENERO AND M. MOSHINSKY, *Instituto de Física, Universidad de México.*—In recent publications[1,2] the elementary particles of the strong interactions were assumed to be built from three basic particles: proton (p), neutron (n) and Λ. It was assumed also[2] that p,n,Λ are three states of a single particle and that these states form a basis for representation of the unitary unimodular group in three dimensions (SU_3) that would be the natural generalization of the unitary unimodular group in two dimensions (SU_2) that leads to the concept of isotopic spin for the p,n system. The conservation of strangeness and isotopic spin then requires the irreducible representations of SU_3 in which SU_2 is explicitly reduced. There is also the possibility of discussing the representations of SU_3 in which the orthogonal three dimensional group R_3 is explicitly reduced.[3] This last representation leads to the concept of seniority for the composite elementary particles. The meaning and usefulness of this concept in the field of elementary particles will be discussed.

[1] S. Sakata, Progr. Theoret. Phys. **16**, 686 (1956).
[2] Ikeda, Ogawa, and Ohnuki, Progr. Theoret. Phys. **23**, 1073 (1960).
[3] V. Bargmann and Moshinsky, Nuclear Phys. **18**, 697 (1960); **23**, 177 (1961).

Y2. The Composite Pion. PETER KAUS* AND W. K. R. WATSON, *University of Southern California.*—Following the original suggestion of Fermi and Yang[1] and subsequent authors[2] that a pion can be described in terms of a bound state of a nucleon antinucleon pair held together by a vector meson field, we have explored the possibility further in the light of the recent work of Gell-Mann,[3] which suggests that there may be as many as nine vector mesons. At the present time there is reasonable evidence to indicate that the octet is characterized by a coupling constant in the neighborhood of $\frac{2}{3}$. However, the singlet B_0 which couples the nucleon current could conceivably have a larger coupling constant, sufficient to cause the necessary binding of almost 2 Mc^2. Results based on several models will be discussed.

* Consultant and J.P.L., California Institute of Technology.
[1] E. Fermi and C. N. Yang, Phys. Rev. **76**, 1739 (1949).
[2] E.g., R. Finkelstein, S. Gasiorowicz, and P. Kaus, Can. J. Phys. **32**, 480 (1954).
[3] M. Gell-Mann, Phys. Rev. (to be published).

Y3. On the Decay of K and π Mesons. JUAN DE OYARZABAL, *Instituto Nacional de la Investigación Científia y Universidad Nacional de México.*—Lowest order calculations of decay rates and energy spectrum of the decay products of k- and π-mesons decays have been performed using the form of boson currents suggested by Zeleny and Barut[1] and taking account of the possibility of the existence of an intermediate boson.

[1] W. B. Zeleny and A. O. Barut, Phys. Rev. **121**, 908 (1961).

Y4. Equilibrium Configuration and Fission Barrier for Nuclei with High Angular Momentum. DANIEL SPERBER, *Armour Research Foundation.*—There is experimental indication that fission barrier decreases with increase of angular momentum. Pik-Pichak's[1] calculation of the barrier for nuclei with a charge close to the critical charge and rotational energy small in comparison with the surface energy confirms this idea. Hiskes[2] and Beringer and Knox[3] calculated only the equilibrium configurations of rotating uniformly charged nuclei for wider ranges of charge and angular momentum. In the present calculation, attention is limited to nuclei with zero charge. The shape of equilibrium and fission barrier are calculated for the entire range of angular momenta for which a rotating droplet held together by surface tension has stable equilibrium. It is shown that a liquid drop, originally spherical as angular momentum increases, first takes shapes of oblate spheroids, that upon further increase the shapes of equilibria become concave at the poles, and that finally the poles coalesce and a ring form is created. It is also shown that the nature of equilibrium changes with the change of the topology of the equilibrium configuration.

[1] G. A. Pik-Pichak, Soviet Phys.—JETP **7**, 238 (1958).
[2] J. R. Hiskes, University of California Radiation Laboratory—9275 (1960).
[3] R. B. Beringer and W. J. Knox, Phys. Rev. **121**, 1195 (1961).

Y5. Energy Levels of Li^7.† F. C. KHANNA,* Y. C. TANG, AND K. WILDERMUTH, *Florida State University.*—The energies of the low-lying levels in Li^7 are calculated with a variational method. The trial wave functions incorporate the features of relatively long range correlations as the clustering of nucleons in the nucleus. To simplify computations, the L-S coupling scheme has been used throughout. The ^2P and ^2F doublets are considered in an alpha cluster plus triton cluster representation. The resulting energy values for the $^2P_{3/2}$, $^2P_{1/2}$, $^2F_{7/2}$, and $^2F_{5/2}$ levels are calculated to be -37.4, -36.9, -32.5 and -31.5 Mev, respectively. The $^2F_{5/2}$ level, so far undetected experimentally, is found to have a large level width. The $^2P_{3/2}$ level at 7.47 Mev is examined in a Li^6 cluster plus neutron representation. The energy obtained for this state agrees fairly well with experiment. Extensive calculations have also been carried out to determine whether a positive parity level with an excitation energy around 6–10 Mev exists. Our results indicate that in both representations which we considered, such a level cannot be formed. Our finding, therefore, casts considerable doubt upon the existence of a positive parity state at 6.54 Mev, as is indicated by some experiments.[1]

† Partially supported by the Office of Naval Research.
* On leave from Punjab University, Chandigarh, India.
[1] F. Ajzenberg-Selove and T. Lauritsen, Nuclear Phys. **11**, 1, (1959).

Y6. Effects of Residual Interactions in Spectra of Odd-A and Odd-Odd Deformed Nuclei.* N. K. GLENDENNING AND S. G. NILSSON, *Lawrence Radiation Laboratory.*—In comparing level schemes of a sequence of odd-Z isotopes one observes relative energy shifts of the intrinsic proton states by energies of the order of 100 kev. This may be ascribed to differences in the interaction energy of the odd proton with the neutron pair added when passing to the heavier isotope. The diagonal energy of an interaction of Gaussian shape and finite range is calculated for a sequence of odd-Z isotopes and odd-N isotones. Various exchange mixtures are studied. A test of the most appropriate exchange mixture is provided by $K_n \pm K_p$ doublets identified in several deformed odd-odd nuclei.

* Supported by the U. S. Atomic Energy Commission.

Y7. Extended Shell Model Calculations and Effects of Nonlinearity of Density Matrix Equations.* J. SAWICKI AND T. SODA, *University of California, Berkeley.*—Equations for the off-diagonal components of the single particle density matrix of a finite system of fermions are linearized with the inclusion of exchange terms taking into account part of the

nonlinearity effect due to the exclusion principle. The leftover terms bilinear in the density operator are then "minimized" by a method somewhat similar to that discussed by Sawada[1] and Sawada and Soda.[2] The effect of the resulting correction terms is estimated on the example of the giant dipole state in O^{16} and is found small giving support to the random-phase approximation. A successive approximation perturbation procedure based on this method can be useful in applications to finite nuclei.

* Supported in part by the U. S. Air Force Office of Scientific Research.
[1] K. Sawada, P. R. 119, 2090 (1960).
[2] K. Sawada and T. Soda (submitted to Phys. Rev.)

Y8. Constituent Nuclides in the Periodic System. NICHOLAS EFREMOV, *New York.*—The regularities of the isotopic composition of the chemical elements have already led us to the conclusion that the nuclei of the atoms of some chemical elements (e.g., Mg, Si, Ca, Fe, Ni, etc.) can be considered as "the constituent nuclides."[1] We have shown the possible nuclear reactions leading to the generation of the constituent nuclides as follows: $C_{12}+C_{12}=Mg_{24}$, $C_{12}+O_{16}=Si_{28}$, $Mg_{24}+O_{16}=Ca_{40}$, $Mg_{26}+Mg_{26}=Cr_{52}$, $Mg_{26}+Si_{30}=Fe_{56}$, $=Fe_{56}$ etc. As a result of certain harmonic mass relations between their isotopes these chemical elements must be very abundant. The observed abundance of these chemical elements in the universe—in stars, the sun's atmosphere, the composition of meteorites, and in the composition of our planet—is in good agreement with that conception. This theoretical conception can also explain the composition of the iron meteorites, the paragenests of the chemical elements (O, Mg, Si, Fe, Ni, etc.) in the composition of the stone meteorites, as well as the existence of the pallasites—transitional formations between stone meteorites and iron meteorities. Further experimental substantiation of such nuclear reactions would be of great interest, although the latest experiments of the Canadian scientist E. Almquist, concerned with the generation of nuclear molecules and constituent nuclides ($C_{12}+C_{12}=Mg_{24}$) were a very important first supporting proof.

[1] N. Efremov, Zeitschrift der deut. geol. Ges. 102, 2 (1950).

SATURDAY AT 14:30

Auditorium 3

(M. N. ROSENBLUTH presiding)

Plasma II

Z1. Collisionless Plasma Shock Waves. HIDEO YOSHIHARA, *Convair-San Diego* (introduced by I. Oppenheim).—An exact solution for the profile of a collisionless plasma shock wave in the absence of magnetic fields has been found for the nonlinear Vlasov equations composed of the collision-free Boltzmann equations plus Poisson's equation. The uniform shock speed is taken intermediate to the positive ion and electron temperatures of the ambient plasma; this case is of interest to satellite motion in the upper ionosphere. If the most probable speed of the electrons is much greater than the shock speed, the Boltzmann equation for the electrons yields a Maxwellian distribution for the electrons under the influence of the Coulomb potential. For the positive ions we require the distribution function to approach a Maxwellian far upstream. Additionally far upstream and downstream of the shock we require charge neutrality, a vanishing Coulomb force and a steady distribution function for the positive ions. Under these conditions it is found that a solution exists for a given shock Mach number only for a definite ratio of the electron to positive ion temperatures in the quiescent plasma. Distribution of the various macroscopic properties through the shock are computed for a shock wave speed ratio of $(20)^{\frac{1}{2}}$.

Z2. Linear Wave Coupling in a Cold Periodic Plasma. R. A. GERWIN, *Boeing Scientific Research Laboratories.*—A plasma containing a plane compression wave is considered. The electrons alone are responsible for the plasma phenomena. Given an arbitrary initial distribution of small longitudinal and transverse electric fields, they are followed in time, using hydromagnetics and are obtained in terms of a power series in which the expansion parameter is the compression wave amplitude. The more series terms that are used, the longer the field expressions are valid in time. For very small times, essentially only nearest neighbor modes couple, i.e., the longitudinal and transverse parts of an electric field of wave vector $\mathbf{k}$ each produce longitudinal and transverse fields of wave vectors $\mathbf{k}\pm\mathbf{k}_0$, where $\mathbf{k}_0$ is the compression wave vector. This is similar to nonlinear mode interaction as studied by Sturrock. For slightly longer times, there is coupling to next nearest neighbors, etc. Bragg reflection and diffraction grating properties appear as special cases of this mode coupling. For plasma oscillations whose wave vectors are collinear with $\mathbf{k}_0$, it is found that, although the spatial envelope of the oscillations is constant in time, the component k modes decay like $1/t^{\frac{1}{2}}$ for long periods of time.

Z3. Reversible Heating by Magnetic Pumping.* LAURENCE S. HALL, *Lawrence Radiation Laboratory, Livermore.*—Continuous reversible heating of a plasma by the use of a time-varying magnetic field having an appropriate nonsinusoidal waveform is discussed. Three limiting cases are analyzed, and the efficiency of the schemes (which resemble Carnot cycles) is shown to be improved over that found in the more conventional computations using sinusoidal varying fields.[1–3] Rates of power input to typical plasmas are calculated for a number of illustrative examples.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] J. M. Berger *et al.*, Phys. Fluids 1, 301 (1958). See also L. Spitzer, Jr., and L. Witten, "On the ionization and heating of a plasma," NYO-999 (1953) (unpublished), and J. M. Berger and W. A. Newcomb, "Heating of a plasma by magnetic pumping," NYO-6046 (1954) (unpublished).
[2] A. Schluter, Z. Naturforsch. 12a, 822 (1957).
[3] L. S. Hall, A. L. Gardner and D. A. Edwards, "Plasma heating by transit-time magnetic pumping in single-transit systems," UCRL-4752 (1956) (unpublished).

Z4. Flow of Low-Density High-Speed Plasma through a Magnetic Barrier. M. A. GILLEO, *Lockheed Missiles and Space Division.*—A theoretical treatment[1] has been worked out which specifies the penetration of a magnetic barrier of height ΔB above a guiding field B_o by a plasma stream in terms of the speed of the stream, the temperatures and masses of the ions and electrons, and the barrier ratio $\Delta B/B_o$. Experiments have been made in which all of these variables were measured or known except for the ion temperature. A stream of hydrogen plasma is fired from a coaxial gun into an evacuated ($<3\cdot10^{-6}$ mm) tube with $B_o=780$ gauss. Data obtained with a Johnson-Malter double probe yield a plasma speed of $1.3\cdot10^{7}$ cm sec^{-1}, a maximum-number density n of $5\cdot10^{13}$ cm^{-3}, and the electron temperature T_e. In the leading edge

of the stream at the position of the barrier T_e is as high as 6 ev; in the maximum-density portion $T_e \approx 4$ ev; and in the trailing portion T_e drops to 2 ev and lower. For the maximum-density portion a reduction by 10% of n after the barrier is not observed until $\Delta B/B_o$ reaches 4.6; a reduction of 50% is observed for $\Delta B/B_o = 17.8$; as $\Delta B/B_o$ approaches the maximum available value of 25.2 the reduction becomes >60%. The data for the transmitted fraction vs $\Delta B/B_o$ are closely fitted by a curve calculated for an ion temperature of 7.1 ± 0.2 ev.

[1] M. A. Gilleo, Phys. Fluids **4**, 210 (1961).

Z5. Plasma Acceleration in the Electromagnetic Region. I. RF Experiments. G. S. JANES AND A. BRATENAHL, *Avco-Everett Research Laboratory.*—The electromagnetic region of magnetohydrodynamics has been defined[1] as that low-density domain in which the mean free path and the ion gyro radius are larger than the apparatus size or characteristic length, while the electron gyro radius and the Debye shielding length are still relatively small. In this domain, the magnetic containing and accelerating forces can be transmitted directly to the electrons but can only be transmitted to the ions indirectly as a consequence of the charge neutrality requirement. Steady-state rf experiments utilizing the traveling magnetic cusp configuration show this acceleration mechanism to be very effective, the striking feature being the appearance of strong electrostatic fields which are closely correlated with the ion accelerations. The experimental evidence includes detailed thrust, heat-transfer, and electrostatic-probe measurements, as well as mass flow rate and energy balance considerations. It has not been possible to accelerate a plasma in the electromagnetic domain with a moving magnetic mirror configuration because of the presence of continuous magnetic field lines which permit the secondary flow of electrons counter to the direction of acceleration.

[1] A. R. Kantrowitz and H. E. Petschek, "An introductory discussion of magnetohydrodynamics," in *Magnetohydrodynamics*, edited by R. K. M. Landshoff (Stanford University Press, Stanford, California, 1957).

Z6. Plasma Acceleration in the Electromagnetic Region II. dc Experiments. A. BRATENAHL, G. S. JANES, AND A. R. KANTROWITZ, *Avco-Everett Research Laboratory.*—The electromagnetic region of magnetohydrodynamics has been discussed in the preceding abstract, together with experimental evidence for plasma acceleration in a traveling magnetic cusp field in the electromagnetic region. This traveling wave mode is characterized by a strong axial dc electric field, which is responsible for accelerating the ions and which has led to the suggestion that an externally applied axial dc electric field might improve the performance. The mean plasma velcoity has been doubled by this method. A model is proposed in which the drift of electrons relative to the magnetic cusp field is controlled by leakage through cusps and by collisions with walls, while the motion of the ions, on the other hand, is controlled by electric fields and occasional collisions with walls. Under these conditions, the ion mobilities are greater than the electron mobilities.

Z7. Coaxial Plasma Accelerator. PHILIP J. HART, *Lockheed Missiles and Space Division.*—The behavior of coaxial electrodes in accelerating a plasma is investigated both theoretically and experimentally. An analog computer is used to solve simultaneous differential equations simulating two situations: (1) The coaxial electrodes are used in a shock tube originally filled with a gas of uniform density; and (2) the coaxial electrodes are used to accelerate a constant mass of gas into a vacuum. The solutions include plasma displacement, velocity, acceleration, the current and its derivatives, and various power terms as functions of time. For the first case, plasma velocities within the electrode system, measured from streak photographs for several experimental arrangements, coincide very closely with the predicted velocities until the peak velocity is attained; at this instant, which is the assumed limit of validity of the equations, a shock wave detaches from and moves ahead of the plasma disk. The actual current distribution in the space between the electrodes, as determined by a "difference" magnetic probe, is found to be rather complex, with current loops forming after the peak velocity is attained. Reasons are given why the simple model still predicts velocities with good accuracy.

Z8. Particle Trapping in a Mirror Machine with a Spatially Rotating Magnetic Field.* H. J. KARR, E. A. KNAPP, J. A. PHILLIPS, E. J. STOVALL, JR., AND J. L. TUCK, *Los Alamos Scientific Laboratory.*—The transfer of particle velocity from the longitudinal to the transverse direction by a stationary helical perturbation on a longitudinal magnetic field, as proposed by R. C. Wingerson, has been studied experimentally and theoretically. The perturbing magnetic field is adjusted to be continually perpendicular to the trajectory of a particle injected axially transferring longitudinal into transverse energy. Perturbations of the particles magnetic moment on subsequent traversals determine the efficiency of this device as a trap. Results show transfer of $\geq 70\%$ of energy from the axial to the transverse direction for an injected electron beam. On subsequent traversals perturbations of $<1\%$ are observed for transits in the backward direction where the sense of rotation of helix and reflected particle are opposite, however, during transit in the initial direction the particle may be in resonance with the perturbing field for short distances with large changes ($\leq +20\%$) in the longitudinal velocity. Machine computations show the same general behavior. The balance of transit perturbations in the two directions indicate that collisionless trapping for ~25 reflections with a 5:1 mirror geometry should be possible.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

Z9. Magnetic Field Asymmetries in Pulsed Mirror Geometries (Orthogonal Pinch).* J. W. MATHER, *Los Alamos Scientific Laboratory.*—Small magnetic perturbations affecting the angular symmetry of the axial magnetic field (B_z) can be produced by (1) the fringing field of a bar magnet (≈ 70 gauss) placed alongside the driving coil, and (2) the noncylindrically symmetric cross section of the coil proper. The latter perturbation is inherent in most axial field compression devices as a result of the current connections to the coil. For a coil 15 cm long, 6.6 cm in diameter, and with mirror ratio 1.02:1, the above perturbations reduce the neutron yield from a D_2 discharge by a factor of ~3. That the magnetic field is unevenly distributed at the mirrors is shown by the nonuniform distribution of surface damage to the metal. The feed-point spacing asymmetry is minimized by decreasing the gap spacing from 0.062 to 0.010 in. Without cylindrically symmetric electric fields, some ionized particles may strike the walls before a current sheath is formed producing (1) contamination and (2) nonuniform detachment. Magnetic field asymmetries may lead to earlier breakup of the plasma as found in other devices. These results emphasize the importance of field symmetry during gas breakdown.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

Z10. Plasma Acceleration and Compression in Strong-Gradient Geometries.* RALPH W. WANIEK, *Advanced Kinetics, Inc.*, H. FISCHER, *Cambridge Research Laboratories*, AND S. W. LEE, *Advanced Kinetics, Inc.*—Experiments have been performed to study transiently generated plasma configurations in the field of Helmholtz and counter-Helmholtz geometries with internal injection.[1] Such systems are achieved in

practice by the coupling of asymmetric strong-gradient coils in the proper electromagnetic configuration. The results to be presented were obtained with uv-sensitive image converters operated with a 0.2 μsec gate width and using RCA 7200 photomultipliers. These were used to detect the details of plasma growth and disappearance. Small pickup probes of high resonant frequencies were adopted to monitor field perturbations and the diamagnetic properties of the plasma.

* Research supported by the Electronics Research Directorate of the U. S. Air Force Cambridge Research Laboratories.
[1] R. W. Waniek, H. Fischer, and K. J. Park, Bull. Am. Phys. Soc. 6, 196 (1961).

Z11. Experimental Investigation of the Structure of Shock Waves Produced in a MAST.* RICHARD M. PATRICK, *Avco-Everett Research Laboratory* (introduced by A. Kantrowitz).—An experimental investigation of the structure of shock waves produced in a magnetic annular shock tube (MAST) has been reported.[1,2] Recently, the change in the magnetic field across these shock waves has been measured. These measurements give a collision-free shock thickness which agrees with the previous results.[1] The change in the field agrees with the value predicted using the Rankine-Hugoniot equations in conjunction with the measured shock speeds and plasma density behind the shock.[3] Additional measurements of the dependence of the collision free shock thickness on the Alfvén Mach number have been obtained. The range of plasma densities has been extended to 10^{17} parts/cm^3. The over-all shock thickness (the order of 1 mm) obtained at high densities by monitoring the radiation across the annulus indicates that the angle between the plane of the shock and the normal to the wall is equal to or less than 2°.

* Supported by the U. S. Air Force through the Air Force Office of Scientific Research.
[1] R. M. Patrick, Phys. Fluids 2, 589 (1959).
[2] F. J. Fishman, A. R. Kantrowitz, and H. E. Petschek, Revs. Modern Phys. 32, 959 (1960).
[3] N. H. Kemp and H. E. Petschek, Phys. Fluids 2, 599 (1959).

Z12. Heat Transport from a Hot Plasma.* MORTON CAMAC AND ROBERT FEINBERG, *Avco-Everett Research Laboratory*.—Experimental measurements of the heat-transfer rates on the side wall of the magnetic annular shock tube (MAST)[1] have been initiated with the use of a new type of heat-transfer gauge that works in the presence of strong electric and magnetic fields. A portion of the stainless-steel shock-tube wall is replaced by a thin sapphire window coated with a 1000-A carbon layer. The shock-heated plasma comes in contact with the carbon. Infrared radiation from the back surface of the carbon is sensed with a fast 0.1 μsec rise-time ir detector. With this rise time the system can determine temperature changes of a few degrees of objects at room temperature. The system was calibrated by measuring the heat transfer from air in the reflected shock region in a chemically driven shock tube. Observations are in agreement with the theory of Fay and Riddell.[2]

* Supported by the U. S. Air Force through the Air Force Office of Scientific Research.
[1] R. M. Patrick, Phys. Fluids 2, 589 (1959).
[2] J. A. Fay, and F. R. Riddell, J. Aeronaut. Sci., 25, 73 (1958).

SUPPLEMENTARY PROGRAMME

SP1. Nuclear Structure. GERTRUDE TIRING SCHWARZMANN.*—Since 1947 at various Meetings of the American Physical Society a microphysics has been expounded, based on the interpretation of particle waves as alternating currents with direct current components; of corpuscles and waves as *alternate equivalent* states of the elementary entities of matter and those of light, having in both states a quantity of inertia $2h \cdot f/c^2$ and $h \cdot f/v^2$ in case of light and matter, respectively; of spin motion as full-fledged motion; of materialization as decomposition of a light wave into a pair of particle waves. Two light waves simultaneously materialize into a proton and an electron pair. Instantaneous formation of an antineutron prevents redematerialization of both pairs, because nuclear antiproton and satellite positron are in antineutrons in the particle state. He^4 consists of two coorbital antineutron-proton pairs, revolving in opposite senses about a common vacant center. C^{12}, Ne^{20}, Si^{28}, consist, respectively, of 3,5,7 alphas, each antineutron-proton pair revolves in *one* sense between two pairs, revolving in the *opposite* sense about a common center. Stable nuclei contain a core of equal and/or different formations, consisting each of odd numbers of alphas.

* To be given at the end of Session U if the Chairman rules that time permits.

SP2. Study of the $C^{12}(He^3,n)O^{14}$ and the $C^{13}(He^3,n)O^{15}$ Reactions in the Energy Range 7 to 10.5 Mev.* H. W. FULBRIGHT, J. W. VERBA, AND V. K. DESHPANDE, *University of Rochester*.—The $C^{12}(He^3,n)O^{14}$ and $C^{13}(He^3,n)O^{15}$ reactions have been studied with a beam ranging in energy from 7 to 10.5 Mev. Angular distributions of neutrons leading to the ground states of O^{14} and O^{15} have been obtained. The angular distributions are strongly forward-peaked with no appreciable backward peak or intermediate bump. The distributions are fitted with the approximate double stripping formula $W(\theta) \sim \exp(-K^2/4\gamma^2)|j_L(kr_0)|^2$ with $L=0$.[1] An excitation curve was obtained at 0°. Absolute cross sections have been found in each case.[2]

* To be given at the end of Session S if the Chairman rules that time permits.
[1] H. C. Newns, Proc. Phys. Soc. 76, Pt. 4, 489 (1960).
[2] Work supported by the U. S. Atomic Energy Commission.

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Proceedings of the American Physical Society

Minutes of the Thirteenth Annual Gaseous Electronics Conference Held at Monterey, California, on October 12, 13, 14, and 15, 1960

THE Thirteenth Annual Gaseous Electronics Conference was held at the U. S. Naval Postgraduate School, Monterey, California, on October 12, 13, 14, and the morning of October 15, 1960. The conference was jointly sponsored by the Division of Electron Physics, the Office of Naval Research, and the U. S. Naval Postgraduate School. The registration was over 300. The decision to have a three and one-half day meeting permitted the acceptance of fifty-six of the contributed papers submitted. There were sessions on Surfaces and Cathodes, Positive Column, Basic Processes, Propagation in Plasmas, Diagnostics, Breakdown, and Oscillations.

Four invited papers were presented:

Scope and Limitations of a Fully Adiabatic Law in Collision-Free Plasmas. O. Buneman, *Cambridge and Stanford Universities.*

General Properties of the Four Modes of Wave Propagation in a Plasma. J. L. Delcroix, *University of Paris.*

Microwave Whistler Mode Propagation in a Dense Laboratory Plasma. Roger Gallett, *National Bureau of Standards, Boulder.*

Thermal Radiation from a Plasma with and without Magnetic Fields. G. Bekefi, M.I.T.

The Conference banquet was addressed by Lewi Tonks of the General Electric Company who spoke on "Irving Langmuir's Plasma."

The Conference Committee for the coming year consists of W. P. Allis, *Chairman*; C. J. Gallagher, *Secretary*; N. P. Carleton, N. L. Oleson, J. M. Richardson, G. J. Schulz, and R. N. Varney. The Fourteenth Conference in 1961 will be held at the General Electric Company in Schenectady, New York. Abstracts of the contributed papers are printed below.

N. L. Oleson, *Secretary*
Thirteenth Annual Gaseous
Electronics Conference

A1. Sputtering of Monocrystalline and Polycrystalline Copper by Argon Ion Beams.* P. D. Skiff, H. K. Reynolds, J. C. Allred, and J. A. Brandt, *University of Houston.*—In bombarding the (111) face of a monocrystalline copper target with a normally incident beam of argon ions of energy in the range of 20 to 140 kv, preferential directions of ejection of the copper atoms were observed. An ejection pattern similar to those obtained recently at much lower ion energies was clearly evident and did not change at higher energies. The directions of ejection corresponded to perpendiculars to the (110), (101), (011), (114), (141), and (411) planes of the target lattice. Recent work by Koedam and Hoogendoorn[1] indicated that the (114), (141), and (411) pattern disappeared at ion energies above 1500 v, and Rol[2] *et al.* reported (100), (010), and (001) ejection at 20 kv. Sputtering yields of argon ions bombarding polycrystalline copper have been measured. Sputtered atoms were collected on glass and the film thickness measured by multiple beam interferometry. At 45° bombarding angle, results range from 13 atoms/ion at 20 kev to 9 atoms/ion at 160 kev.

* Supported by the U. S. Atomic Energy Commission and the Office of Naval Research.
[1] Koedam and Hoogendoorn, Physica **26**, 351 (1960).
[2] P. K. Rol *et al.*, Proceedings of the 4th International Conference on Ionization Phenomena in Gases, Uppsala (1959).

A2. Etch Effects from Oblique Ion Bombardment.* P. A. Harkins, G. D. Magnuson, and B. B. Meckel,† *Convair.*—It has been found that metallic surfaces of Cu, Au, Al, Ta, Mo, and Ni, when bombarded with 500-v Hg^+ ions at angles of incidence other than zero, exhibit a definite surface structure or pattern. This pattern consists of hillocks or spires oriented parallel to the direction of the incoming ion beam. In Cu and Ni, steps oriented perpendicularly to the ion beam were also found. This surface pattern provides visual evidence that the sputtering process at low ion energies is a momentum transfer process. Since redeposition of sputtered atoms on the hillocks and steps could be quite large, angle of incidence yield measurements could be in error unless they are made before hillocks form. It is believed that the hillocks are formed by the more rapid removal of surrounding material, causing the hillocks to stand out in relief. It is not known what causes the reduced sputtering rate at the hillock, but evidence will be presented indicating that the cause is a line imperfection in the solid.

* This work was supported by U. S. Air Force contract.
† Now at Geophysics Corporation of America, La Jolla, California.

A3. Sputtering Threshold.* D. E. Harrison, Jr.,† and G. D. Magnuson, *Convair.*—We attempt to give a logically coherent definition of the term "sputtering threshold" and establish criteria which *may* determine an experimental threshold. The Silsbee chain mechanism and the experimentally obtained preferred direction of emission from single crystals are used to establish a threshold theory. Two models are required, one generally applicable when the mass ratio is less than one, and another when it is greater than one. Single crystal threshold laws are obtained, and polycrystalline laws follow for fcc crystals by averaging the single crystal forms. An approximate technique for the evaluation of surface atomic binding energies is presented so that the thresholds can be compared with experimental results. In all cases the theoretical thresholds are less than, or comparable to, experimental "thresholds."

* This work was supported by U. S. Air Force contract.
† Permanent address: University of Toledo, Toledo, Ohio.

A4. Spectroscopic Studies of Sputtering.* G. K. Wehner and Robley V. Stuart, *General Mills, Inc.*—A sensitive spectroscopic method for measuring sputtering yields is described. Instantaneous readings for yields down to 10^{-5} atoms/ion can be obtained by measuring, with a monochromator and photomultiplier, the intensity of a resonance line in the emission spectrum of the target atoms which, after being sputtered, are excited in dense, magnetically concentrated, low-pressure plasma. This method does not, as most other methods do, require an accumulation of sputtered material for measurements. One can therefore clean the target surface with higher energy ions immediately before

taking a reading at low energy. Results are presented for several metals under Ne^+, Ar^+, Kr^+, Xe^+, and Hg^+ ion bombardment at energies down to 20 ev. It is found that serious errors may arise at very low energies from doubly charged ions which bombard the surface with double kinetic energy. In the threshold region, even a small number can become very important. As a consequence, sputtering yields at very low bombarding energy have been overestimated in the past. We find, in all cases studied so far, that yields are less than 10^{-6} atoms/ion at 25 ev.

* Work was sponsored by the Office of Naval Research and the U. S. Air Force Cambridge Research Center.

A5. Hollow Cathode Highly Ionized Discharge.* C. MICHELSON,† *Oak Ridge National Laboratory*,‡ AND D. J. ROSE, *MIT and ORNL*.—A highly ionized plasma is made by the prescription: gas flow (H_2, He, A, N_2) 0.3–2 cc STP/sec through a refractory hollow cathode tube; any anode; 30–200 v dc. An axial induction 100–1000 gauss is used for collimation and assistance in rf starting; the induction can be removed during operation. The discharge runs from the cathode interior, where $p_0d \approx 1$ cm×mm Hg. If the ions sputter or vaporize the cathode material, the cathode interior forms a cavity. Typical conditions are: 3-mm diam cathode, 50-amp, 35-v, 0.5-cc/sec argon, external pressure 3×10^{-4} mm Hg, cavity pressure 40 mm Hg, cathode temperature 2500°C, electron temperature 1–2 ev with high energy tail. Currents 2–200 amp have been run; the configuration can be modified considerably at will. Charge densities are 10^{12}–10^{14}/cm³ in the exterior plasma and 10^{16}–10^{17}/cm³ inside the cavity. Calculations show that a neutral gas molecule has little chance of reaching the extermal plasma without being ionized, consistent with observations.

* This work was supported in part by the U. S. Army (Signal Corps), the U. S. Air Force (OSR, ARDC), and the U. S. Navy (ONR), and in part by the U. S. Atomic Energy Commission and the National Science Foundation.
† On loan from the Tennessee Valley Authority.
‡ Operated for the U. S. Atomic Energy Commission by Union Carbide Corporation.

A6. Partition of Power between Tungsten Electrodes in dc Low-Pressure, Inert Gas and Tungsten Vapor Arcs. HEINZ G. SELL AND A. E. LAMARCHE, *Westinghouse Electric Corporation*.—The relative heating of a tungsten anode and cathode of equal dimensions in electrode-stabilized arcs of helium, argon, and xenon and in tungsten vapor between tungsten electrodes of a vacuum-arc melting furnace has been investigated as a function of pressure at pressures lower than atmospheric. Abnormally high cathode heating, even to temperatures higher than that of the anode, occurs below a certain threshold pressure, which is lower in xenon than in argon and lowest in tungsten vapor. A study of the arc voltage dependence on electrode separation and gas pressure in a wall-stabilized neon discharge has revealed that the magnitude of abnormal heating is directly related to the anode fall and its relative position in the arc. Abnormal cathode heating is caused by an ion current which is generated when the discharge becomes obstructed and the cathode fall increases greatly as compared to normal heating which is the result of a thermally produced ion current at higher gas pressures. The relationship between abnormal cathode heating, first ionization potential of the arc medium, and ionic mean-free path is discussed. The partition of power is defined as the ratio of the energy liberated by an electron current at the anode to the energy liberated by a positive ion current at the cathode. This ratio is less than 1 when the discharge is obstructed and is close to 10 at higher pressures.

A7. Theoretical Treatment of Gas-Filled Thermionic Energy Converters. W. BLOSS, *Institut fuer Gasentladungstechnik und Photoelektronik*.—The theoretical efficiency of high-vacuum, thermionic-energy converters with usual emitter materials is calculated. It is shown that the optimal temperature for conversion and the normal operating temperature of the emitter are nearly the same for low work function emitters. Comparison is made with energy converters containing a low pressure noble gas filling. By partly ionizing the gas, space charge is compensated and the efficiency in comparison with high-vacuum converters may be increased considerably.

A8. Resistance Heating in the Arc Cathode Spot Zone. J. A. RICH, *General Electric Research Laboratory*.—For an understanding of the arc cathode spot mechanism, it is essential to determine the relative importance of Joule heating within the cathode and the energy input from the arc discharge. The problem of a source of uniform current density acting over a circular area on the surface of a semi-infinite solid of conducting material is formulated and solved with the following results: (1) The Joule heat developed in the hemispherical volume directly under the cathode spot amounts to 38% of the total Joule heat developed in the electrode; (2) a comparison of the energy input to the cathode spot zone due to Joule heating and the energy input due to positive ion bombardment shows that, for current densities of the order of 10^6 amp/cm², the former amounts to some 10–20% of the latter for high resistivity metals such as bismuth, antimony, and mercury. As the current density is increased to 10^7 amp/cm², the two energy sources become comparable for metals other than the low resistivity metals such as copper and silver; (3) the time required to bring typical electrode materials to the melting point with resistance heating only is relatively short. For $J=10^6$ amp/cm² and a spot radius of 2×10^{-3} cm, bismuth (271°C) requires 3.4 μsec, antimony (631°C) 35 msec. The boiling point of mercury (357°C) is reached in 14.5 μsec.

A9. Continuous Retrograde Motion of a Mercury Arc. CHARLES G. SMITH, *Mystic Transformer Company*.—The anchored cathode spot racing around a clean mercury-wettable molybdenum anchor is most intense at the leading edge. It tapers off essentially exponentially to the rear. A half-length of the spot along the direction of motion was, in a particular case, about one cm. These observations and their supporting background add to the phenomenological picture. Previously, the racing anchored arc has given means of separating the characteristic spot spectrum from that of the surrounding regions. Further studies of the anchored arcs have revealed characteristic curves of spot velocity vs magnetic field. Further simplifying studies will be suggested, and the more nearly complete phenomenological picture must lead to an acceptable theory or even new physics—this, in spite of the large number of theories already advanced to explain the electron liberation and the retrograde motion of the cathode spot.

B1. Pressure Constriction of the Positive Column.* R. G. FOWLER AND L. W. JONES, *University of Oklahoma*.—A theory of the well-known pressure constriction was developed some years ago,[1] but very little actual experimental data existed at that time with which to compare it. An investigation has now been completed in several gases which has provided data in good agreement with this theory. Pulsed columns have been studied to remove falsifying influence of species changes owing to metastable and molecular formation.

* Supported in part by the U. S. Office of Naval Research.
[1] R. G. Fowler, Proc. Phys. Soc. (London) **48**, 130 (1955).

B2. Recombination Stabilized Positive Columns with Positive Characteristics in the Rare Gases with and without N_2. CARL KENTY, *General Electric Company*.—Positive characteristics have been found for 1–20 ma positive columns

in 150 mm Xe, Kr, or A with 0.1% N_2 in 10-cm tubes. The discharges are diffuse, substantially filling the whole tube. With Xe+N_2, a continuous spectrum only is emitted; but with Kr or A, some first positive bands of N_2 are prominent. Beyond a critical current, the discharge changes to a thread-like form of much lower voltage, emitting the line spectrum of the rare gas and having a negative characteristic. The positiveness of the characteristic is believed to result from (1) the disappearance of ions by dissociative recombination rather than diffusion to the walls and (2) the effect of single stage ionization resulting from a stationary (Boltzmann) population of the long-lived (1-sec) N_2 metastables. For similar current densities, the gradient varies little with tube diameter. Probe measurements indicate that the electron and ion density is relatively constant across a large central part of the tube. The pure rare gases, now under study, also have low current diffuse discharges emitting continua only and having positive characteristics. However, the gradients are much higher (5–10 fold) and a uniform column is attained only many tube diameters away from the hot cathode.

B3. Computation of Field and Conductivity Distributions across an Electrodeless Ring Discharge. HANS U. ECKERT, *Convair.*—A previously presented method[1] for approximate, simultaneous solution of the wave equation and the electron balance equation applied to an inductive, diffusion-controlled rf discharge of cylindrical geometry is carried further. The radial distributions of electric and magnetic field intensities, of gas conductivity, current density, etc., are obtained in absolute terms. While the evaluations procedure is iterative in general, it is straightforward in the limits of high and low conductivity which closely cover many cases of practical significance. If the conductivity is low enough to make the skin depth larger than the tube radius, absorption of the wave is negligible and vacuum solutions apply for its intensity. If the skin depth is small, or if the product gas pressure times tube radius is large, the conductivity distribution is so nearly uniform that the well-known solutions of the field equations in terms of Bessel functions may be applied. The method is illustrated by practical examples for hydrogen.

[1] Hans U. Eckert, Bull. Am. Phys. Soc. 5, 371 (1960).

B4. Stability of the Slow-Pinch Discharge.* A. A. WARE,† *General Atomic.*‡—The slow-pinch discharges observed in Zeta, Sceptre, and in other experiments exhibit a gross hydromagnetic stability which has been previously unexplained. Since the magnetic fields in these discharges are observed to have little or no magnetic shear, the stability of a discharge with constant pitch magnetic field is considered on the basis of the energy principle. Of the two types of instability which are predicted theoretically, namely "kink" and "interchange" instabilities, the experimental results suggest that only the interchange instability is occurring in practice. Some suggestions are put forward to explain the apparent stability against the "kink" type instability.

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† On leave of absence from Associated Electrical Industries Research Laboratory, Aldermaston, Berkshire, United Kingdom.
‡ John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic Division of General Dynamics Corporation, San Diego, California.

B5. Trapping and Confinment of a High-Density Electron Cloud. RALPH H. BARTRAM, HERMAN O. DRESSEL, AND GERHARD E. WEIBEL, *General Telephone & Electronics Laboratories, Inc.*—Experiments are described in which a cloud of electrons is trapped in a cylindrical chamber and kept in stable confinement by static electric and magnetic fields. Trapped electrons are accumulated in a controlled manner by injection of an electron stream into a potential well which is made progressively deeper during the accumulation period. A sensitive and nondestructive method has been developed for measuring the quantity of trapped charge; it consists of application of a UHF signal to the end electrodes of the trapping chamber and measurement of the impedance presented by the trapped charge as a function of frequency. This type of measurement yields the charge density as well. Pulses applied to the end electrodes are used to determine the distribution of electrons with respect to binding energy in the potential well. An electron cloud 1 cm long and 2 mm in diameter with a density of $5\times10^{10}/cm^3$ has been trapped and confined for at least 5 msec. Electrons resulting from ionization of the residual gas are still present in the chamber after 10 sec.

B6. Instability of a Positive Column in a Magnetic Field.* GEORGE A. PAULIKAS, T. K. ALLEN,† AND ROBERT V. PYLE, *Lawrence Radiation Laboratory.*—The properties of the helical instability[1] that occurs when the longitudinal magnetic field on a positive column exceeds a critical value B_c have been studied in H_2, D_2, He, Ne, and A gases for several pressures, discharge tube radii, and lengths of magnet. As an example, a He discharge at a pressure of 0.22 mm Hg in a 2.75-cm radius tube exhibits an oscillation with a frequency of 6×10^4 sec^{-1}, a wavelength of 78 cm, and an amplitude e-folding rate of roughly 2×10^4 sec^{-1} when the 200-cm long magnetic field is slightly higher than B_c (655 gauss). These parameters, as well as values of B_c, are in good agreement with predictions of the perturbation theory of the positive column proposed by Kadomtsev and Nedospasov.[2] Measurements of B_c are also compared with the sheath instability theory of Hoh.[3]

* Work was performed under the auspices of the U. S. Atomic Energy Commission.
† Visitor from AERE, Harwell.
[1] T. K. Allen, G. A. Paulikas, and R. V. Pyle, Bull. Am. Phys. Soc. 5, 314 (1960).
[2] B. B. Kadomtsev and A. V. Nedospasov, J. Nuclear Energy, Part C, 1960 (to be published).
[3] F. C. Hoh, Phys. Rev. Letters 4, 559 (1960).

C1. Optical Model Analysis of Electron-Hydrogen Scattering.* B. A. LIPPMANN AND H. M. SCHEY, *Lawrence Radiation Laboratory.*—Although the optical model replaces a many-body problem by an equivalent one-body problem, the correct optical model potential is usually unknown until the many-body problem has been solved. However, when target and scattering particles are well separated, perturbation theory is applicable; the relevant part of the scattering problem then can be solved and the asymptotic form of the optical potential evaluated. In the near region, the optical potential can be approximated by imposing the symmetry conditions the exact wave function is known to obey. Applied to elastic e-H scattering, this approach is equivalent to (and therefore justifies) the heuristic procedure of Martin, Seaton, and Wallace,[1] which leads to scattering lengths close to the Rosenberg, Spruch, and O'Malley[2] limits. The method can also be applied to inelastic scattering processes.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Martin, Seaton, and Wallace, Proc. Phys. Soc. (London) 72, 701 (1958).
[2] L. Rosenberg, L. Spruch, and T. F. O'Malley, Phys. Rev. 119, 164 (1960).

C2. Measurement of the Transition Probability of the OI 6157A Line in an Oxygen-Hydrogen Plasma. J. B. SHUMAKER AND W. L. WIESE, *National Bureau of Standards.*—Oxygen saturated with water vapor was introduced into a wall-stabilized arc[1] operated at 50 and 100 amp. The absolute intensities of H_β and the OI 6157A line were measured with a scanning photoelectric spectrometer calibrated by means of a standard tungsten strip lamp. The electron density was determined from the line profile of H_β, using Stark broadening theory. The population in the upper state of the oxygen line was then evaluated assuming local thermodynamic equilibrium

and a pure oxygen plasma. The added hydrogen impurity and possible variations in its concentration with arc radius do not sensibly affect these calculations because of the practically identical ionization potentials and partition function ratios for oxygen and hydrogen and the very low relative concentration (2%) of hydrogen. The oxygen transition probability agrees well with values obtained by two other methods.[2]

[1] H. Maecker, Z. Naturforsch. **11a**, 32 (1956).
[2] G. Juergens, Z. Physik **138**, 613 (1954).

C3. Collisional Detachment of Negative Ions in Molecular Oxygen.* A. V. PHELPS AND J. L. PACK, *Westinghouse Research Laboratories.*—Negative ions formed in oxygen at low E/p are observed to undergo collisional detachment at oxygen temperatures above about 400°K. The negative ions are formed in a drift tube as a result of three-body collisions between electrons and oxygen molecules.[1] As the ions drift through the tube, electrons are released in collisions of the negative ions with oxygen molecules. The electrons are separated from the ions using an "electron filter."[2] The probability of collisional detachment is calculated from measurements of the attachment probability and the ratio of the electron current produced by detachment to the electron current traversing the tube without attachment. These results are consistent with the formation of O_3^- ions in the three-body attachment process and the detachment of electrons by the inverse process, i.e., $O_3^- + O_3 \rightarrow e + 2O_2$. The ratio of the thermal detachment frequency to the thermal attachment frequency can be used to estimate the electron affinity of molecular oxygen. Preliminary results show satisfactory agreement with the results obtained by Loeb.[3]

* Supported in part by the Air Force Research and Development Command.
[1] L. M. Chanin, A. V. Phelps, and M. A. Biondi, Phys. Rev. Letters **2**, 344 (1959).
[2] L. B. Loeb, *Basic Processes of Gaseous Electronics* (University of California Press, Berkeley, California, 1955), Chap. V, especially p. 4

C4. Measurement of Electron Transfer Collision Cross Sections for Negative Ions in Gases.* T. L. BAILEY AND P. MAHADEVAN,† *University of Florida.*—Inelastic collisions of negative ions in molecular gases are being investigated with a new collision chamber which uses the rf electron filter principle to separate quantitatively slow electrons formed by collisional detachment from slow heavy negative ions produced by electron transfer and other inelastic processes. In cases where simple electron transfer is the only process which yields heavy negative ions, measurements made with this collision chamber give separately the absolute cross sections for electron transfer and for electron detachment. Measurements made with 70–345 ev O_2^- ions in O_2 gas show that the apparent electron transfer cross sections rise with decreasing ion energy from 8.56A² at 345 ev to 21.67A² at 70 ev. The electron detachment cross sections drop slowly with decreasing energy from 8.04A² at 345 ev to 6.69A² at 70 ev. In this energy range, the sum of the detachment and exchange cross sections is in fairly good agreement with the total inelastic cross sections determined by Hasted and Smith[1] and by Muschlitz.[2]

* Supported by the Office of Naval Research.
† Present address: Physics Section, Convair, San Diego.
[1] J. B. Hasted and R. A. Smith, Proc. Soc. (London) **A235**, 349 (1956).
[2] E. E. Muschlitz, Jr., Proceedings of the Fourth International Congress on Ionization Phenomena in Gases, Uppsala, 1A52 (1960).

C5. Study of Electron Attachment in Oxygen Using Electron Beams.* G. J. SCHULZ, *Westinghouse Research Laboratories.*—Electron beam techniques have been extended to higher pressures (up to 0.5 mm Hg) in order to observe the three-body attachment processes in oxygen. A magnetically aligned, electron beam traverses a collision chamber, and the negative ions are collected on a cylindrical collector surrounding the collision chamber. The retarding potential difference method is used to study the effect of nearly monoenergetic electrons. The cross section for production of O^- is measured at low pressures. The pressure dependence of the O^- current is linear up to about 10^{-2} mm Hg and joins smoothly into a quadratic dependence at higher pressures, in agreement with a theory by Allis for the transition from a long mean-free path to a short mean-free path. At high pressures (above 10^{-1} mm Hg) and low electron energies, the production of O_2^- is observed. The O_2^- current peaks at about 0.1 ev and decreases to low values at 1 ev. The pressure dependence of the current indicates that the O_2^- is formed in a three-body collision.

* This research was supported in part by the Advanced Research Projects Agency and the Office of Naval Research.

C6. Electron Loss Processes in Nitric Oxide Plasmas at Low Pressures. R. C. GUNTON AND E. C. Y. INN, *Lockheed Missiles and Space Division.*—Plasmas consisting of NO^+ ions, electrons, and NO molecules have been produced by photoionization. Lyman alpha radiation, from a pulsed hydrogen capillary light source, was admitted into a small quartz cell containing nitric oxide through a lithium fluoride window, transparent to the uv radiation. The Lyman alpha photon of 10.20 ev is sufficient to provide the 9.25-ev ionization energy of the molecule. Undesired radiation, which might produce dissociation, was filtered out by an intervening air path. The decay of the ionization, following the light pulse, was observed by placing the quartz cell in the X-band microwave cavity. From the shift in resonance frequency of the cavity, electron densities in the range 10^{10}–10^{9} cm^{-3} were observed. Measurements have been made on the rate of attachment of electrons to NO molecules. At pressures up to 16 mm Hg, attachment appears to follow a 3-body process, as observed by Bradbury,[1] with a rate coefficient of 5×10^{-31} cm^6 sec^{-1} at an electron energy of about 0.04 ev. Other electron loss processes, such as ambipolar diffusion and electron-ion recombination, will be discussed.

[1] N. E. Bradbury, J. Chem. Phys. **2**, 827 (1934).

C7. D/u for Electrons in Helium, Argon, and Hydrogen. J. H. PARKER AND R. W. WARREN,* *Westinghouse Research Laboratories.*—The ratio of the diffusion coefficient to the mobility for electrons in helium, argon, and hydrogen has been measured at 77 and 300°K for an E/p range of 10^{-3} to 10 v/cm-mm Hg. The "Townsend Method" is used, in which D/u is obtained from the measured lateral spreading of electrons at a given E/p. To obtain the relationship between D/u and the lateral spreading, it is necessary to solve the mobility-diffusion equation with zero density boundary conditions at the walls of the chamber. The solution that is used in the present study, while being based on the method of images as developed by Huxley,[1] differs significantly from the solution that he obtained by this method.[1] The results of the present study are pressure independent for pressures greater than approximately 30 mm Hg and in agreement with the theoretical values of Frost and Phelps.[2] For pressures less than approximately 30 mm Hg, the results are found to depend on pressure. A possible explanation of this dependence will be discussed.

* Supported by Air Research and Development Command.
[1] L. G. Huxley, Phil. Mag. **7**, 396 (1940).
[2] L. S. Frost and A. V. Phelps, Bull. Am. Phys. Soc. **5**, 122, 371 (1960).

C8. Ionic Mobilities in Hydrogen. LORNE M. CHANIN, *Honeywell Research Center.*—Previously reported techniques[1] for the measurement of the mobilities of positive ions have been used to study the mobilities of positive ions in hydrogen from $E/P_0 = 3$ to 50. Results at room temperature at low E/P_0 are in good agreement with the data obtained by

Lauer[2] and Mitchell.[3] As E/P_0 is increased, the present results merge with the data obtained by Rose.[4] Measurements have also been conducted at 195 and 77°K. The present results which indicate an increasing mobility with decreasing temperatures lie approximately 10% below the theoretical values of Mason and Vanderslice[5] for H_2^+.

[1] M. A. Biondi and L. M. Chanin, Phys. Rev. **94**, 910 (1954).
[2] E. J. Lauer, J. Appl. Phys. **23**, 300 (1952).
[3] J. H. Mitchell, quoted by A. M. Tyndall, *The Mobility of Positive Ions in Gases* (Cambridge University Press, New York, 1938).
[4] D. J. Rose, J. Appl. Phys. **31**, 643 (1960).
[5] E. A. Mason and J. T. Vanderslice, Phys. Rev. **114**, 497 (1959).

C9. Wigner Rule and Multiple State Transfer of Excitation in Helium.* ROBERT M. ST. JOHN AND RICHARD G. FOWLER, *University of Oklahoma.*—Observations have been made on light emission from certain low triplet levels of helium gas traversed by a monoenergetic electron beam. Helium pressure and electron energy were varied. A major part of the triplet excitation was formerly assigned to direct transfer from ^1P states in gross violation of the Wigner Spin Conservation rule. Transfer of excitation by a new process is proposed wherein the conflict with the Wigner rule is minimized by greatly reducing the cross sections required by data to values near the gas-kinetic value. It is assumed that may ^1P states, including those with large quantum number n, transfer excitation energy to neighboring triplet states having closely corresponding principal quantum numbers. The triplet states thus formed in turn populate low-level, triplet states by radiative transitions. It is found that states lying between $n=6$ and $n=20$ play the dominant role in the transfer process. The new multiple-state transfer process is used in the deviation of qualitative explanations of several additional transfer phenomena.

* This work was supported by the Air Force Office of Scientific Research.

C10. Theory of the Multiple State Transfer of Excitation of Helium.* CHUN C. LIN AND RICHARD G. FOWLER, *University of Oklahoma.*—A theory is presented to explain the multiple-state mechanism for the transfer of excitation from singlet to triplet states in helium atoms proposed by St. John and Fowler. The spin-orbit interactions of the intra- and inter-atomic type are believed to be responsible for the singlet-triplet transfer in the highly excited states. It is shown that a helium atom in an upper nP state, after colliding with a normal atom, transfers primarily into either a P or an F state. Qualitative results derived from this theory are in good agreement with the essential features of the new process.

* Part of this work was supported by the U. S. Air Force Office of Scientific Research.

D1. Phase Reversal of the Electric Field in High-Frequency Plasmoids.* ALBERT J. HATCH, *Argonne National Laboratory.*—High-frequency plasmoids of the type first observed by Wood[1] are formed between plane parallel metal electrodes, 25 cm in diameter and 15 cm apart, by a 15-Mc/sec exciting frequency. Axial rf electric fields, resulting from the applied voltage and from the plasma, are detected with an rf probe technique previously described.[2] A 15-Mc/sec probe signal, as observed in the absence of plasma or in the presence of a multipacting plasma ($p<0.1\mu$), is always in phase with the applied voltage. In the pressure range from 5–100 μ, the magnitude of the 15-Mc/sec signal within the plasma is very nearly zero. In the high-frequency plasmoids (0.1–5 μ), however, the phase of the observed 15-Mc/sec signal is shifted by approximately 180°. The amplitude of this signal increases as the pressure is reduced toward the 0.1 μ extinction value. The apparent dc potential of the plasmoid is positive. The results appear to be explainable on the basis of the self-potential of an axially oscillating electron cloud in the plasmoid.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] R. W. Wood, Phys. Rev. **35**, 673 (1930).
[2] A. J. Hatch, Bull. Am. Phys. Soc. **3**, 152 (1959).

D2. Propagation at Microwave Frequencies along a Fluctuating Plasma Column.* M. A. ALLEN AND G. S. KINO, *Stanford University.*—Random fluctuations of plasma number density, which are present as standing or traveling waves in an arc discharge plasma column, affect the dispersion characteristics of a microwave signal propagating along the column. The examination on a spectrum analyzer of the signal, as it propagates along the column, reveals a transfer of energy into sidebands of the original frequency. This degradation of the microwave signal is shown to be due to phase modulation of the signal caused principally by the strong fluctuation which occurs in mercury-arc discharges at about 100 kc/sec. The phase modulation was examined in detail, both with this internally produced modulation and an externally applied modulation of the number density. The results obtained were explained by the theory of phase modulation, with the depth of modulation being independently measured by means of cavity resonator techniques.

* Supported by Air Force Research Division, Air Research and Development Command.

D3. Nonlinear Interaction of an Electromagnetic Wave with an Anisotropic Plasma Layer.* ROMAYNE F. WHITMER AND EAMON B. BARRETT, *General Telephone and Electronics Laboratories, Inc.*—The theory of electromagnetic wave propagation through an anisotropic ionized layer, including the effects of the nonlinear terms in the Boltzmann transport equation, will be presented. The method of solution of the nonlinear equations involves an expansion of all of the dependent variables in a Fourier series in time. The differential equations describing the propagation phenomena are then solved, for each frequency in the series, for plane wave propagation. A solution in closed form has been obtained, under small signal conditions, for the hth harmonic of the Fourier series. A discussion of the properties of the wave at the second harmonic frequency as a function of the dc magnetic-field strength, the electron density, the electron-neutral particle collision frequency, the field strength of the incident wave, and the thickness of the plasma layer will be presented. Experimental verification of the theoretical predictions, as well as a measured of the range of validity of the "small signal" assumption, has been obtained.

* This research was supported by the U. S. Air Force.

D4. Ion Resonance in a Multicomponent Plasma. S. J. BUCHSBAUM, *Bell Telephone Laboratories.*—Experiments, designed to study the phenomena associated with ion cyclotron resonance in a plasma which contains two or more ion species with different charge to mass ratios, will be described. The experiments utilize the positive column of a steady-state discharge, a static magnetic field of 88 kgauss (or less), and rf frequencies in the Mc/sec band. The gases studied were hydrogen, helium, and neon. At low electron densities ($n<\epsilon_0 B^2/M$), the plasma, when forced into oscillations transverse to the magnetic field, exhibits a resonance at the cyclotron frequency of each ion. At large plasma densities, the motion of each (heavy) charged-particle species is tightly coupled to the other plasma constituents through space-charge fields. The result is a set of hybrid resonance frequencies equal in number to the number of different ions in the plasma.[1] The parameters which determine the hybrid frequencies and the widths of the experimentally observed lines will be discussed.

[1] S. J. Buchsbaum, Phys. Fluids **3**, 418 (1960).

D5. Measurement of Shift in Cyclotron Cutoff. DEREK W. MAHAFFEY, *Boeing Scientific Research Laboratories.*—Experiments have been carried out to test a theory of microwave propagation through a hot magnetoplasma.[1] The mode investigated was that of right-hand, circularly polarized microwaves propagating parallel to the direction of the steady magnetic field. The theory predicts a shift in the electron-cyclotron resonance cutoff frequency, the amount of the shift depending on the ratio of electron pressure nkT to magnetic field pressure $H^2/8\pi$. The experiments were conducted using a PIG discharge placed between the pole pieces of an electromagnet, giving a field strength uniform to within 0.25% over the working volume. The discharge was pulsed through argon gas with a pulse duration of about 4 msec. X-band microwave equipment was used. The radiation and receiving antennas were in the form of crossed slots cut in straight sections of waveguide incorporated in the cathodes of the discharge tube. A shift in the cutoff frequency in the expected direction was found. The magnitude of the shift and its dependence on the parameters of the discharge are in qualitative agreement with the theory.

[1] J. E. Drummond, Bull. Am. Phys. Soc. **3**, 86 (1958); Phys. Rev. **112**, 1460 (1958).

D6. Transverse Normal Modes in a Cylindrical Plasma. W. D. HERSHBERGER, *University of California,* AND RICHARD L. MOORE, *Richard L. Moore, Consultants, Los Angeles.*—The reflection and absorption spectrum of a cylindrical plasma column may be elicited and observed at a fixed microwave frequency by varying the current through the column. The electric field of the incident wave is perpendicular to the axis of the column. The secondary resonances occur at values of current and electron density lower than that required for the principal resonance. The positions of the members of the spectrum are given by an interference-dispersion relationship given in an earlier paper.[1] The frequency ratios for the various observed modes are given equally well by the ratio X_{m1}/X_{11}, where X_{m1} is the lowest value of x for which the value of the mth-order Bessel function $J_m(X_{m1})$ is zero. An interpretation of the spectrum is given in which the resonances are identified with the transverse normal modes of the plasma column, and the assumptions and approximations underlying this interpretation are discussed.

[1] W. D. Hershberger, J. Appl. Phys. **31**, 417–422 (1960).

D7. Conductivity, Absorption, and Emission of Microwaves.* LUDWIG OSTER, *Yale University.*—The different methods currently used in computing the interaction of microwaves with plasmas, such as the evaluation of absorption and emission coefficients and conductivities, are compared. It is shown that they are all based on the same model assumptions and thus are equivalent. Power absorption and emission are then expressed in terms of temperature and density of the plasma. The resulting formulas are discussed as to their accuracy for numerical applications and their range of validity. Special consideration is given to deviations from equilibrium, both as the microwave field and the velocity distribution of the particles are concerned.

* Supported by the Office of Naval Research.

E1. Re-Examination of the Meaning of Magnetic Probe Measurements.* RICHARD L. MOORE, *Richard L. Moore, Consultants.*—The axial component of the magnetic field in a cylindrical plasma is shown to be proportional to the difference between two angular velocities, that of the ion gas and that of the electron gas when the radial density is a quasi-stationary error function. By use of the functional relations between the variables, angular velocity is eliminated to obtain density as a function of the magnetic field, the initial mass per unit length (M), and the standard deviation of the magnetic field curve (σ) (in rationalized mks units) as follows:

$$\rho(r) = \frac{M}{2\pi\sigma^2}\left[\frac{H_s(r) - H_s(r_0)}{H_s(0) - H_s(r_0)}\right]\frac{kg}{m^3}.$$

This expression shows that the internal magnetic field is frozen in and carried with the material. It gives a more consistent interpretation of density from probe measurements than present theory. It suggests that the snowplow plasma sheath model is not consistent with experiment but should be replaced by a bell-shaped plasma centered on the axis.

* Supported by Northrop Corporation, Norair Division, and by Rome Air Development Center, U. S. Air Force.

E2. Probe Curves and Their Second Derivatives in Double Sheaths. G. MEDICUS, *Wright-Patterson Air Force Base.*—Families of probe curves and their second derivatives are automatically plotted for the probe passing through a sheath across the opening of a hollow hot cathode in Ne of about 1 mm Hg. The electron accelerating sheath is followed by a weak retarding field towards the anode. (1) At the anode side sheath edge, two distinct groups of electrons are indicated, a slow group consisting of electrons having suffered inelastic collision losses, and a fast group with most of the energy acquired in the sheath retained. (2) In the middle of the sheath, the slow group is absent, so that the probe curve goes linearly through space potential in accordance with theory for spherical probes. (3) At the cathode side sheath edge, a slow group is indicated. In case (2), an approximate indication of space potential can be expected from the ion current which should cause a small kink in the second derivative, as long as the ion energy remains small compared to the electron energy (good energy exchange of ions with neutrals). Actually, such kinks are observed.

E3. Influence of Diffusion Losses on the Probe Potential in a Dense Plasma. KLEBER S. MASTERSON, JR.,* *U. S. Naval Postgraduate School,* AND G. ECKER, *Universitat Bonn.*—The theory of exploring probes in a plasma, as originally developed by Langmuir, does not apply to probes with dimensions comparable to or larger than the mean free path of the plasma carriers. On the other hand, it frequently seems necessary or desirable to use such probes for the investigation of the plasma qualities. We have calculated the relation between the measured probe potential and the true probe potential for two types of probes, with and without a magnetic field. The results for larger probe dimensions show a strong influence of the diffusion losses, which causes asymmetric distortions of the measured potential distributions. The deviations depend on the kind and the size of the probe.

* Lieutenant, U. S. Navy.

E4. Study of Langmuir Probes in a Continuous Electrodeless Gas Discharge. HENRY R. HUNCZAK, *NASA Lewis Research Center.*—A preliminary investigation was conducted of the double-probe[1] method of determining electron temperatures in a plasma generated by 3.75- to 10-Mc rf discharges in air and hydrogen. Electron temperatures of 6 to 11 v were measured. Log plots of the current-voltage characteristic (I) indicated a Maxwellian distribution of electron velocities in a voltage range where neither probe was saturated. Electron temperatures, as calculated from the slope of the log plot, agreed within 6.5% with those determined from an "equivalent resistance" method.[1,2]

[1] E. O. Johnson and L. Malther, Phys. Rev. **80**, 58 (1950).
[2] K. Yamamoto and T. Okuda, J. Phys. Soc. Japan **11**, (1956).

E5. Studies of Diamagnetism in Gaseous Plasmas with Spin-Resonance Methods. T. C. MARSHALL, R. A. KAWCYN, AND L. GOLDSTEIN, *University of Illinois.*—It has been possible to observe the occurrence of diamagnetism in active

discharges by measuring shifts in spin absorption resonance frequencies of foreign substances located near the plasma. Narrow spin *electronic* resonances in DPPH have been used to show that the magnetization of a gaseous plasma in low pressure mercury vapor increases linearly with applied magnetic field up to about 40 gauss, where maximization occurs. Observation of the phase change in the Larmor precession of *protons* in a strong homogeneous field showed that the diamagnetism in a modified PIG discharge in noble gases increased linearly with power input and decreased approximately as $1/H$. Irradiation of the plasma with high power microwaves with frequency near the free electron gyro-frequency resulted in an increase of diamagnetism of the PIG discharge. The discharge magnetic moment ranged from -10^{-3} to -0.32 erg/cm³-gauss, depending on experimental conditions. The sensitivity of the *nuclear* resonance technique is one part in 10^6. It permits observation of diamagnetism to be deferred until the discharge is over. Theories of Alfven and Gordon, which attribute the diamagnetism to diffusion processes, appear to be correct, but the results are more general than these derivations would imply.

E6. Temperature and Energy Balance in an Electrodeless rf Thermal Plasma. THOMAS B. REED, *Lincoln Laboratory,* MIT.*—A new type of electrodeless thermal plasma, generated by 4-Mc rf is described. Temperatures have been measured as a function of radius in argon and argon-gas mixtures using the Lorenz method with inversion of the Abel integral equation. Peak temperatures of 16 000°K in argon and 19 000°K in an argon-20% oxygen mixture were measured. Energy losses associated with conduction, convection, and radiation mechanisms have been measured. Total power transferred to the plasma ranged from 1.6–3.1 kw, which was in all cases about 50% of the total power consumed.

* Operated with support from the U. S. Army, Navy, and Air Force.

E7. Lowering of the Ionization Potential in an Argon Plasma. H. N. OLSEN, *Union Carbide Corporation.*—Radial intensity distributions of the total electron continuum (free-free+free-bound) emitted from an atmospheric argon arc plasma have been measured on an absolute intensity scale at fixed wavelengths over the range 3000 to 12 000 au. All radial distributions show an off-axis peak which falls at the same radius for each frequency. From earlier work,[1] the measured temperature at the position of this peak was found, by the Fowler-Milne method, to be 16 000°K. From the frequency dependence of $\log\epsilon$, an experimental value of 0.85 v has been obtained for the lowering of the ionization potential which is consistent with the observed disappearance of lines in the spectrum. This compares well with the theoretical value of 0.79 v, obtained from an iterative calculation of the plasma composition combining the Saha equation with the Ecker and Weizel[2] expression relating ΔV to the electron density but is 50% higher than that given by the well-known Unsold theory. Measured intensities are higher than the theoretical value given by the Krammers-Unsold theory by a factor of about five in the red and two in the visible region of the spectrum.

[1] H. N. Olsen, Phys. Fluids **2**, 614–623 (1959).
[2] G. Ecker and W. Weizel, Ann. Phys. **17**, 126–140 (1956).

E8. Spectroscopic Measurements of Plasma Temperatures and Densities in a High Pressure Cesium Diode. R. DONOHUE, R. MAJKOWSKI, AND HANS GRIEM, *General Motors Corporation.*—Measurements of the electron and atom temperatures have been made in a cesium diode at 7-mm pressure. The electron temperatures (excitation temperatures) were obtained as a function of the position between cathode and anode from the relative intensities of the red (8521 A) and blue (4555.55 A) lines. The atom temperatures were derived from the Doppler broadening (which influences the line core) of both lines. The atom densities were measured from the absolute line intensities using the excitation temperatures. The electron densities were deduced from the collision (Stark) broadening which dominates in the line wings. From the atom and electron densities, the ionization (Saha) temperature was determined. All three temperatures (electron, atom, and Saha) agree to within 20% (i.e., the experimental error). From the measured densities and temperatures, the total vapor pressure was computed and found to agree with the cesium vapor pressure (at cold spot) to within 20% (i.e., within experimental accuracy).

E9. Experimental Observation of Stark Broadening of Balmer Lines.* W. S. COOPER, III, A. W. DESILVA, AND J. M. WILCOX, *Lawrence Radiation Laboratory.*—A hydrogen plasma was prepared by a high-current discharge and was allowed to decay. A pure Balmer spectrum from the plasma, merging with the continuum after nine lines, was observed. An estimate, based on the Inglis-Teller method, gave an ion density of about 3.5×10^{15} cm^{-3}. The line profiles of the first three members of the series, H_α, H_β, and H_γ, were measured as functions of time and were matched with theoretical line profiles calculated by Griem, Kolb, and Shen.[1] Good fits were obtained from very near the center of the lines to a point on the wings where the intensity is down by about two orders of magnitude from the value at the peak (as far as observations were extended). In the 350 μsec during which the line profiles were observed, the ion density decayed from 5.0×10^{15} cm^{-3} to 1.5×10^{15} cm^{-3}, and extrapolated back to about 6.4×10^{15} cm^{-3} at the time the discharge current was terminated, suggesting 100% ionization of the original neutral hydrogen (100μ) at that time. Temperatures were about 10⁴°K.

* Work done under auspices of the U. S. Atomic Energy Commission.
[1] H. R. Griem, A. C. Kolb, and K. Y. Shen, Phys. Rev. **116**, 4 (1959); idem, NRL Report 5455, March 4, 1960.

E10. Underwater Spark as a Gaseous Discharge. C. D. MAUNSELL, *Pacific Naval Laboratory.*—Measurements have been made of the formative time of underwater spark breakdowns after step voltages of 1–15 kv are applied to a point electrode. Both fresh and sea water have been used. The breakdown in the more highly conducting sea water occurs within tens of microseconds while in fresh water hundreds of microseconds are needed. Visual observation shows the formation of a bubble on the electrode at voltages slightly below that at which breakdown occurs. These results are consistent with an hypothesis that resistive heating of the water occurs initially. After the formation of a bubble, a gaseous discharge occurs if the field strength is sufficiently high. The inertia of the water causes the subsequent discharge to produce high temperatures and pressures.

F1. Electronic Computation of the Temporal Growth of Currents in Gases, Including the Effect of Space Charge.* A. L. WARD, *Diamond Ordnance Fuze Laboratories.*—The problem of the temporal growth of current in a gas between parallel plates, including the effect of space charge, has been programmed for electronic computation. The continuity equation for the electron current density, $J_-(x,t)$, is solved by using the exponential growth of $J_-(x,t)$ along an electron "world" line. The partial differential equation for the positive ion-current density $J_+(x,t)$ is solved by a difference method. The field distribution $E(x,t)$ is determined by Poisson's equation. The initial distribution of the electron current density $J_-(x,0)$ and positive ion current density $J_+(x,0)$ across the gap, where x is the distance from the cathode, are those calculated for the static case for the given under-voltage assumed. The initial field distribution $E(x,0)$ is given by the sum of that calculated in the static case and a constant increment, corresponding to a step voltage applied at $t=0$. $J_-(0,t)$ is given by the sum of the constant externally initiated current density and the contribu-

tions of both positive ion and photoelectric secondary effects. $E(0,t)$ is obtained by requiring that the total potential drop across the tube, including any parallel capacitance, and a series resistance should remain constant, or in other cases to vary with a sinusoidal time component. Results of calculations will be prsented.

* Supported by the Office of Ordnance Research.

F2. Electrical Breakdown of Argon in Glass Cells with External Electrodes at 60-Cycle Alternating Potential.* J. M. EL-BAKKAL AND L. B. LOEB, *University of California.*—Breakdown in argon below 35 mm in borosilicate glass cells with external electrodes has been investigated using four different experimental techniques with varied time resolution, including steady and 60-cycle alternating potential. A fairly complete semi-quantitative description of the mechanisms at work has been achieved. Breakdown normally is of the Townsend type with a γ_p from the glass setting in above normal Townsend threshold. Near threshold breakdown is quenched by reduction of the internal field to slightly below threshold by wall charges. At high over-voltages, short-lived but intense breakdowns anihilate the external field and deposit wall charges proportional to the applied potential. Very high over-voltages yield streamer-like breakdown mechanisms of ultra-short rise time. Phenomena are altered by electrical properties of glass. Short duration of discharge confines breakdown to narrow channels, even at lower pressures the charges later spreading over electrode surfaces.

* Work supported in part by the Office of Naval Research.

F3. Ionic Avalanches in D_2 Gas at Very High Field Intensities. G. W. MCCLURE AND K. D. GRANZOW, *Sandia Corporation.*—Ion avalanches initiated by D_3^+ ions in D_2 gas under the action of a very strong electric field ($E/P \simeq 4 \times 10^5$ v/cm mm Hg) are investigated by machine calculations taking into account: (1) the production of fast secondary D_2, D, and D^+ through charge exchange and dissociative collisions, (2) the production of slow ions by ion-molecule collisions, and (3) the interaction of secondary ions with the gas. The avalanche developed in a distance of several times the charge-exchange mean free path is analyzed as to particle content and energy distribution. Favorable comparisons with measured energy spectra of D^+ and D_3^+ ions generated in a high voltage discharge indicate that most of the important processes have been accounted for.

F4. Theory of High Impedance Discharge in Hydrogen. CRAWFORD MACCALLUM, *Sandia Corporation.*—The one-dimensional discharge in hydrogen at pressures below the Paschen minimum has been studied as a function of pressure and applied voltage for various electrode materials and electric field distributions. A generalized concept of "multiplication factor" has been developed which allows it and the asymptotic distribution of ion-electron production to be calculated numerically as solutions of an eigenvalue problem. The results have clarified the essential role played by electrons, backscattered from the anode, and have supplied qualitative information about secondary electron emission by neutral molecules in the kv energy range.

F5. Nonstationary Motion of Electrons in a Gas under the Influence of an Electric Field.* G. ECKER AND K. G. MÜLLER, *Universität Bonn.*—The motion of electrons, as determined by the field acceleration and the elastic and inelastic collisions with the gas atoms, is calculated from the Boltzmann equation. We derive the average velocity and the scattering ellipsoid as a function of time. For particles starting from rest, there exists always a critical electric field E_c depending on pressure and temperature. Below this critical value, electrons approach the stationary drift process. Above the critical value, the electrons do not reach a stationary state; they "run away." For a finite initial velocity v_0 and a field below the critical value E_c, the particles are either accelerated to drift, or decelerated to drift, or "run away," depending on the value of v_0. From a calculation of the scattering parameters, we find, for $E > E_c$, a focusing effect in the velocity space which increases with field strength. Also, the relaxation time for the drift process and the stopping power for electron beams can be calculated.

* Supported by the U. S. Department of Army through its European Research Office.

F6. Effect of Large Stationary Density Gradients upon Electrical Breakdown Transverse to a Hypersonic Stream of Air.* GARY L. MARLETTE, *California Institute of Technology.*—Several new effects are introduced when a dc electrical discharge is struck across a gas moving at hypersonic speeds. The present paper results from an experimental investigation of one of these effects—the large boundary layer density gradients that arise in hypersonic flow over electrodes. The experiments were carried out with air in the Galcit 5-in. by 5-in. hypersonic wind tunnel with a nominal Mach number of 5.8. The dc breadkown voltages were measured across a channel formed by flat-plate "Rogowski" electrodes embedded in two sharp-edged insulating flat plates. The breakdown voltages measured were considerably below the breakdown (Paschen) voltages measured in ordinary gas discharges. A theoretical treatment is given and qualitative agreement with experiment results.

* Supported by U. S. Army Ordnance.

F7. Some Aspects of the Geiger Discharge in Halogen Quenched Counters. K. VAN DUUREN, *Philips' Gloeilampenfabrieken.*—The propagation of the discharge was investigated for halogen counters filled with various Ne-A-Br_2 mixtures. Measurements were done for cylindrical counters with a thin wire as anode, as well as for counters with a spherical electrode geometry. It was found that the mechanism was essentially different for cylindrical counters containing 0.05% Br_2 from what was found for the conventional organic quenched counters. (a) The propagation of the discharge along the anode wire takes place by long range photons. (b) The charge distribution along the length of the anode wire is nonuniform. (c) For larger cathode diameters, the discharge starts along the anode but is transferred within a few microseconds to the region near the cathode surface. The behavior of the dead time of the counter as a function of the counter voltage was measured for various counters. The results could qualitatively be explained by the above-mentioned phenomena. The role of the metastable atoms and molecules and of the resonance photons was investigated by measuring the building up time for various amounts of argon and bromine mixtures. It was found that large variations of argon pressure (a factor of 10) hardly influenced the building up time. However, the building up time was found to be approximately inversely proportional to the bromine pressure. This indicates that the occurrence of resonance photons governs the building up of the discharge and that the metastable atoms and molecules did not play a role with the building up of the discharge.

F8. Light Pulse from a GM Counter Discharge.* W. P. DAVIS, JR., AND W. C. WORTHINGTON, *Dartmouth College.*—The GM counter discharge has been of considerable interest since 1928, but a detailed description of this discharge is still not possible today. It has been felt[1] that an experimental examination of the radiation emitted by the discharge might serve to clarify some of the uncertainties in the propagation mechanism, but very little work[2] has been done in this area.

Light pulses from commercially available end-window GM tubes (Amperex Electronic Corp., Hicksville, New York) have been observed with an RCA 5819 photomultiplier. For overvoltages of about 50 v ,these light pulses are about 1.0 μsec in length and have a distinctive shape. The emission spectrum of the GM discharge above 2800 A was determined using a Hilger spectrograph. Data relating overvoltage to the behavior of the light pulse are presented, as well as a possible interpretation of the shape of the light pulse. Preliminary results using GM tubes with semitransparent cathodes will be presented.

* Supported in part by the National Science Foundation.
[1] L. B. Loeb, Phys. Rev. **113**, 7 (1959).
[2] Locher (unpublished); see Korff, *Electron and Nuclear Counters* (D. Van Nostrand Company, Inc., Princeton, New Jersey, 1955), p. 176; G. A. Condas, Bull. Am. Phys. Soc. **2**, 375 (1957).

G1. Relaxation Oscillations in Synthesized Plasmas.* FRED M. JOHNSON AND KARL G. HERNQVIST, *RCA Laboratories.*—A theoretical and experimental study of internal relaxation oscillations in a plasma diode will be presented. An analysis is made of the steady-state, space-charge modes in a plane-parallel diode. Here, ions and electrons, having a Maxwellian velocity distribution, are emitted from one electrode and are collected by the other electrode. It will be shown that there exists a set of operating conditions for such a plasma diode where no steady-state solution to the space-charge problem is allowed. Furthermore, the analysis indicates that an oscillatory solution exists where the potential fluctuates between a potential maximum and a potential minimum at a rate determined by the ion transit time. Experimental studies of these relaxation oscillations will be described. Tests were made with a low-pressure, cesium vapor type diode, having a high work-function cathode, a low work-function anode, and a small probe in the interelectrode space. Oscillations in the frequency range ½–1 Mc/sec were observed in this diode. The nature of the oscillations as well as the conditions necessary for their occurrence are in good agreement with the theoretical analysis.

* Part of this research was sponsored by Advanced Research Project Agency, Department of Defense.

G2. Some Measurements of Fluctuations in a Plasma.* F. W. CRAWFORD AND J. D. LAWSON, *Stanford University.*—Measurements of the fluctuations in anode voltage, tube current, and number density have been made in a hot-cathode, mercury-vapor discharge at a pressure of ~1 μ, under both space-charge-limited and temperature-limited emission conditions. Substantial low-frequency fluctuations occur from zero to several hundred kc/sec, with strong components at ~60 and ~100 kc/sec. Potential distribution curves show noise generation over the first 20 cm of the plasma column. This is poorly correlated from point to point but appears to propagate in the electron thermal-velocities range. Over the remaining 50 cm of the experimental tube, the signal is well correlated and travels at $>10^9$ cm/sec. Despite the nonuniform noise distribution, the column appears as a uniform impedance (to external signals), and an approximate expression has been derived for it impedance/frequency characteristic. Number-density measurements, made by a microwave cavity perturbation technique, indicate fluctuations increasing in amplitude towards the cathode and persisting even when the discharge is temperature-limited and other fluctuations have been substantially reduced.

* Supported by U. S. Atomic Energy Commission.

G3. Influence of the Anode on Moving Striations.* A. W. COOPER, *U. S. Naval Postgraduate School.*—The connection between multiple anode spots and the moving striations in the positive column of a glow discharge in argon has been investigated photoelectrically. Two spots, oscillating out of phase on a cylindrical anode, give rise to separate nonsinusoidal light intensity waves which travel towards the cathode. These patterns merge to form the nearly sinusoidal striation waveform in the positive column. A 50-v longitudinal potential oscillation of variable frequency applied to the anode glow region controls the striation frequency over a range of 30% of its natural value. Experiments previously reported[1] have shown the critical current for disappearance of moving striations to increase with tube diameter. Thus, a long discharge tube, containing a center section of large diameter between narrower end sections, can exhibit a normal striation pattern in the wide section while the end sections, which are operted above the critical current, show no oscillation. There is, then, no detectable mechanism connecting the striation oscillation pattern and the anode glow.

* Supported by the Office of Naval Research.
[1] A. W. Cooper and N. L. Oleson, Bull. Am. Phys. Soc. **5**, 371 (1960).

G4. Experimental Two-Beam Excitation of Electron Oscillations in a Plasma. M. J. KOFOID, *Boeing Scientific Research Laboratories.*—Extensive experimental tests have been completed to establish the conditions under which strong standing waves of longitudinal electron oscillations can be excited in a plasma by two independent oppositely directed electron beams, without sheaths on the beam emitting electrodes. Strong excitation was obtained when the velocity with which the electrons of each beam entered the plasma was equal to the phase velocity divided by the quantity $(n+\frac{1}{4})$ or $(n+\frac{3}{4})$, when $n=1, 2, 3, \cdots, 6$. It was not neccessary to have equal beam velocities. A method of analysis has been worked out for finding the transit times for electrons having the above-indicated preferred entrance velocities and entering the plasma at different angles of oscillation-frequency phase. Assuming different maximum plasma oscillation electric-field intensities, transit times have been analyzed for conditions under which strong standing waves have been excited experimentally. These calculations permitted study of the electron bunching which is believed essential to the excitation of oscillations. The experiments were made with 1.0-mm diam beams passing through 2.0 cm of plasma; standing waves were excited with one, two, or three loops at frequencies of 450–930 Mc.

G5. Oscillations in the Argon Subnormal Glow Discharge.* D. J. BELKNAP, M. J. REDDAN, AND A. L. WARD, *Diamond Ordnance Fuze Laboratories.*—In the course of measurements of static characteristics in the subnormal glow region, the transition region between the Townsend and the normal glow discharge, various oscillatory phenomena have been noted in argon at pressures of 50 mm Hg and lower. These oscillations range from nearly sinusoidal oscillations of very small amplitude to relaxation-type oscillations of large amplitude. Under certain tube and circuit conditions, relaxation-type oscillations occur, the frequencies of which are nearly independent of the value of the series resistance, contrary to the usual case. The frequency of these oscillations is proportional to the current. Both the amplitude and frequency of these oscillations are strongly dependent upon any capacitance parallel to the tube. At very low currents, a repeating sequence of a growing oscillation, which leads to a "breakdown" pulse, has been observed. Pictures will be shown of various current waveforms. Further explanation of the various phenomena will be given, and the circuit requirements for tube stability will be discussed.

* Partially supported by the Office of Ordnance Research.

G6. Solution for the Two-Electron Correlation Function. BURTON D. FRIED, *Space Technology Laboratories, Inc.*, AND H. W. WYLD, JR., *Space Technology Laboratories, Inc., and University of Illinois.*—Consideration of two-particle cor-

relations provides a systematic method for correcting the Vlasov or "collisionless" (more accurately "correlationless") kinetic equation. Existing treatments have retained the two-particle correlation function, $g(x_1,v_1,x_2,v_2,t)$, only in the limit $t\to\infty$. By studying the Laplace transform, $g_L(\omega)$, one can find how rapidly $g(t)$ actually approaches its asymptotic value. We restrict ourselves to a classical, nonrelativistic electron gas, interacting via Coulomb forces in the presence of a uniform background of positive charge. When the one-electron distribution function f is independent of position, $g_L=g_L(x_1-x_2, v_1, v_2, \omega)$ satisfies an integral equation which can be solved in closed form for the special choice $f(v)=(a/\pi)(a^2+v^2)^{-2}$. It is found that the "universal" poles in g_L (i.e., those not associated with particular initial conditions) consist of one at $\omega=(v_1-v_2)\cdot p/2$ (giving rise to an oscillatory term in g) and a number of (damped) poles lying on the lines $\omega=-ipa$ and $\omega=-ipa/2$, where p is the wave number conjugate to x_1-x_2. Since for $p\ll\omega_p/a$ the "relaxation time" for g will greatly exceed ω_p^{-1}, these results indicate that the effect of g upon such phenomena as plasma oscillations may not be adequately represented by the $t\to\infty$ limit.

G7. Polarizing Field in a Plasma. O. THEIMER AND L. S. TAYLOR,* *New Mexico State University.*—If an electromagnetic wave travels through a plasma, the plasma electrons (charge $-e$, mass m, velocity v) experience the following forces: $\mathbf{F}_1=-e\mathbf{E}$ is the force from the radiation field E. $\mathbf{F}_2=4\pi\mathbf{P}e/3$ is the force from the polarization charges induced on the surface of a large auxiliary sphere, centered at the test electron. The average force with which the positive ions in the sphere act on a test electron is different from zero because of the radiation induced electron motion and the resulting deviations from randomness. The electron displacement in ordinary space causes the depolarizing force $\mathbf{F}_3$, and the electron displacement in velocity space causes the force of dynamical friction $\mathbf{F}_4$. For low frequencies and weak shielding, these forces satisfy the conventional formulas $\mathbf{F}_3=-4\pi\mathbf{P}/3$ and $\mathbf{F}_4=-m\nu_c\mathbf{v}$, where ν_c is the collision frequency. But both forces tend to zero at optical frequencies and are affected by shielding between opposite charges. Formulas for $\mathbf{F}_3$ and $\mathbf{F}_4$ as functions of frequency, temperature, and electron density are given.

* Now at Missile and Space Vehicle Department, General Electric Company, Philadelphia, Pennsylvania.

MINUTES OF THE 1960 AUTUMN MEETING OF THE NEW YORK STATE SECTION

A SYMPOSIUM on modern advances in physical computers constituted the fall meeting of the New York State Section of the American Physical Society. The meeting was held November 4–5, 1960, on the new and still unfinished campus of Harpur College, the Liberal Arts College of the State University of New York. There were about 200 registrants. The group was welcomed by President Glenn G. Bartle as the first to hold meetings on the new campus, and the physics program in relation to the curriculum at Harpur was discussed briefly by Dean S. S. Gordon and R. H. Penfield, Chairman of the Department. Chairman Renzema responded with a speech of thanks.

A. L. Samuel (IBM) provided background for succeeding papers (all of them invited) by discussing the history and principles of machine computation. W. H. Prince (Eastman Kodak) then illustrated the simple elements of computer programming by considering a hypothetical example. The remainder of the morning session was given over to papers dealing with tunnel diodes, thin films, and microwave devices as computer components. The speakers were L. Esaki (IBM), E. A. Fisch (G.E.), and W. Beam (RPI).

The Friday afternoon session was given over to a tour of the IBM computer production facilities in Endicott. The banquet session on Friday evening was exceptional in that the after-dinner remarks were in keeping with the topic of the meeting. The speaker was Professor Heinz von Foerster, of the University of Illinois, who spoke most engagingly of computational principles as applied to biological systems.

Consideration of modern computer components continued during the Saturday morning session. Magnetic materials were the subject of papers by A. E. Eschenfelder (IBM) and D. O. Smith (MIT Lincoln Laboratory). These papers were followed by those of V. L. Newhouse (G.E.) and D. R. Young (IBM) on the topic of the role of superconductors in the computer field.

Present-day applications of computers were described during the last session of the meeting in papers by J. C. Henry (MIT), G. W. King (IBM), and F. P. Lewandowski (Link Aviation).

A. L. Samuel returned to the stage to summarize the meeting.

Chairman Renzema reported the appointment, in accordance with the constitutional amendment approved at the spring 1960 meeting, of four additional members of the Executive Committee: N. A. Finkelstein, H. Levinstein, D. C. Peckham, and A. F. Turner. These members will serve until the next regular election. The Executive Committee is preparing a slate of officers to be elected in April, 1961. He further reported plans for a meeting in the spring of 1963 at the General Electric Company in Schenectady on the subject of "Biophysics."

ORAN E. MILLER AND D. C. PECKHAM

Minutes of the 1960 Thanksgiving Meeting at Chicago

THE Thanksgiving Meeting of 1960 was held at the old and frequent home of our Thanksgiving meetings, the University of Chicago, to which it is always a pleasure to return. The dates were Friday and Saturday, November 25 and 26. The Local Committee, headed by Frank R. Borchert of the Enrico Fermi Institute of Nuclear Studies, worked with zest and zeal, and managed everything very capably. The programme of the scientific sessions was arranged by the Deputy Secretary with able collaboration from an *ad hoc* Committee of Midwestern advisers. The weather was excellent. The attendance was about 700.

The banquet of the Society was held on Friday evening in the Quadrangle Club. The after-dinner speaker was P.M.S. Blackett, who by fortunate chance was in the region at just the right time to make his presence at the banquet a fortunate fact. The 1960 American Physical Society Prize sponsored by Hughes Aircraft Company was awarded to George Feher. The attendance was a lamentably small 125, but this is partly excused by the fact that Professor Blackett's plans were so indeterminate when the Bulletin went to press that we could not announce him.

Elected to Fellowship on November 25, 1960: Martin M. Block, Charles I. Browne, Calvin M. Class, Leo Esaki, Edgar Everhart, Melvin B. Gottlieb, Andrew Guthrie, Julius L. Jackson, William Edward Keller, William E. Kreger, Bowen Rado Leonard, Jr., Harold Walter Lewis, J. W. McGrath, R. F. Mozley, Henry Winston Newson, Joseph E. Perry, Jr., Gerald C. Phillips, Harold E. Rorschach, Jr., Robert Stratton, Peter A. Sturrock, A. B. Weaver, Philip G. Wilkinson, and Robert Marshall Williamson.

Elected to Membership on November 25, 1960: E. Dwight Adams, Norman W. Albright, Simonne Allard, Adolph B. Amster, Rodney J. Andersen, Armond D. Anderson, Julian Thompson Anderson, Miles E. Anderson, Raymond J. Andres, Frank C. Andrews, Elizabeth M. Arase, Marvin Arenstein, Martin F. Auer, Pinchas Avivi, Edwin C. Balaam, Jr., Raymond Lee Barger, Biswamp Banerjee, Roland Yves Barloutaud, Ralph H. Bartram, Nicolas M. Bashara, H. Dean Batha, H. Carl Beck, Joe R. Beeler, Jr., Diana Iris Bell, Ronald L. Bell, Saul M. Bergmann, Vincent James Berinati, Chander P. Bhalla, Prafulchandra D. Bhavsar, David A. Bilheimer, Kenneth W. Billman, Hans A. Bomke, Warren P. Bird, Harris J. Bixler, Lesser Blum, Richard John Borg, Asok K. Bose, Robert C. Bowe, Julius I. Bowen, Larry H. Brace, Olof Brander, W. J. Bratina, Peter R. Bratt, Neil Brearley, Benny R. Breed, Richard B. Britton, George C. Brown, Jr., F. S. Buffington, Rolf E. Buhler, Ralph W. Burhans, Philip Gary Burkhalter, Leslie L. Burns, Jr., Rudolf Gabriel Buser, Charles D. Butter, Nicola Cabibbo, Bernard Charles Joseph Calnan, L. A. Cambey, George Camey, Carl R. Carlson, Marvin J. Carr, James Barr Carroll, Edward Catalano, Larry L. Caufield, Hong-Mo Chan, John M. Charap, Jack O. Charshafian, Melvyn David Cheslow, Donald Alexander Chisholm, Emerson V. Clarke, Jr., James R. Close, Charles Erwin Cohn, Paul Jerome Coleman, Jr., Richard V. Colvin, Allan L. Conner, Dante P. Contrastan, Ancel E. Cook, John C. Cook, Kendrick V. Cooper, P. J. Coppen, George D. Creelman, James C. Crews, C. Richard Crosby, Frederick Williams Cummings, Earl C. Curtis, Jr., Robert R. Cutler, III, Janusz Dabrowski, Henry Andrew Dahl, Raphael A. Dandl, Victor W. Davis, Peter G. Debrunner, Thomas C. Degges, John K. Dixon, William D. Doyle, Alexander DeVolpi, Edmond Maurice Dewan, Andrew G. F. Dingwall, Donald G. Doran, Clifford J. Dorian, George P. Dorsey, Arwin Adelbert Dougal, Thomas J. Dougherty, Sanford A. Dreskin, Donald P. Duclos, Bruno L. Duelli, Thomas A. Dwyer, Rudolph H. Dyck, Owen C. Eldridge, Jr., Daniel D. Ellemen, Mont R. Ellett, Jack H. Elliott, Albert R. Elwell, Ronald Engelbourg, Joseph Anthony English, Jr., Richard Andrew Eppler, James Harvey Fahs, Leopoldo Maximo Falicov, Jack Felman, Ronald A. Fiore, H. Leonard Fisher, Jr., C. Erman Flanagan, Jr., William M. Foley, Robert M. Folsom, Gilbert C. Ford, J. Stuart Fordyce, Boguslaw Frackiewicz, Paul M. Freedman, Barry T. French, Michael Wulf Friedlander, Ernest P. Gagnon, Robert T. Galla, Anthony F. Gangi, W. Paul Ganley, Robert C. Geldmacher, Nicholas George, Edward Farmer Germain, Alexander N. Gerritsen, Peter D. Gianino, J. Gierula, David I. Gilbert, John A. Gilreath, Richard A. Goings, Andrew Vick Gold, John H. Goncz, Fred Gornick, Meredith C. Gourdine, Eugene P. Greenberg, Irving N. Greenberg, Clarence Albert Greene, Alan H. Griep, Chester E. Grosch, Robert C. Grubinskas, Vincent P. Guinn, Vishwambhar Dayal Gupta, William B. Guth, Reginald Gwin, Augustus Arthur Hackett, Jr., Rudolph Roland Haering, Laurence J. Hagerty, Leonard H. Hall, Arthur T. Halpin, John H. Halton, Warren E. Hammond, Melvin W. Hanna, Osamu Hara, R. J. Happel, Jr., David L. Hardwick, Arie W. Hartman, H. Hasimoto, Bruce R. Hayworth, John F. Healy, Kermit K. W. Heid, William F. Henry, Karl Herman Hering, Karl G. Hernquist, Jan Herrmann, Seymour Willis Herwald, Fred S. Hickernell, Frank J. Hierholzer, Jr., Kichiro Hiida, Jack Hilibrand, Stanton B. Hillier, Larry Lee Hilley, Henry R. Hirsch, James F. Holt, Robert Lloyd Hoover, Jon T. Hougen, Thomas S. Houser, Kenneth C. Huber, Pierre L. Hubert, William F. Hughes, Henry R. Hunczak, Ed V. Hungerford III, George W. Hutchinson, Raymond P. Iczkowski, Edgar L. Irwin, William E. Isler, Fumiaki Iwamoto, William D. Jackson, Miguel Jimenez-Mendez, Charles J. Joachain, Byron Lee Johnson, Tudor W. Johnston, Angel G. Jordan, Nieves Alfonso Jordan, Tadao Kasuya, Ludwig Katz, William Bailey Kaufmann, Hoyt M. Kaylor, Donald C. Kelby, Paul C. Kepple, Gordon Stanley Kino, James L. Kinsey, Joseph Klarmann, Michael M. Klenck, Frederick Bayard Koch, Thomas R. Kohler, Toshiya Komoda, Abraham Kotelchuck, Hans H. Kuehl, Robert Lincoln Lambert, Richard I. Land, Jr., Marshall Lapp, Rudolf R. Larsen, James Donald Lawrence, Jr., Richard F. Leach, Anthony M. Lemos, Edwin Levy, Jr., Shreior S. Lifson, Edward C. Lim, Chia-Jen Lin, Warren J. Little, John B. Lounsbury, Marvin Lubert, Bruno M. Lüthi, Crawford J. MacCallum, Allan Roy Mackintosh, Robert Quinn Macleay, John Malamas, A. John Manuel, Giulio Manuzio, Stanley H. Margolies, Charles Moore Martin, Conrad J. Mason, R. L. Maxwell, Michael E. McCormick, S. Brooks McLane, Jr., Joseph F. McNulty, Robert John Meier, Robert G. Meisenheimer, A. S. Meligy, Clifford W. Mendel, Jr., Edgar Mendelsohn, Gaspar Messina, Akeley Miller, Henry A. Miranda, Jr., Joji Mizuno, Monroe Olin LeVois Moen, Arthur H. Moore, Robert A. Moore, William B. Moore, John J. Moriarty, Rollin John Morrison, Suprokash Mukherjee, George J. Mullaney, James G. Mullen, Charles

J. Mundo, Jr., Harry M. Murphy, Jr., Kenneth M. Murray, Jr., Gerald B. McCauley, John Lacy McKnight, G. T. McNice, Bogdan Nedelkoff, William M. Nelson, Samuel John Newman, Lawrence E. Nielsen, Wendell B. Nix, James P. Nolta, Robert Henry Nowak, Farouk Odeh, Terence W. O'Keefe. Thomas Alfred Oliphant, Theodore A. Olson, Jr., Michael C. O'Riordan, Ludwig F. Oster, Noboru Oti, Carl James Palumbo, Jesus Parrilla-Calderon, Joseph Pasternak, Rolf Torsten Pauli, Nathan Pelner, Benjamin J. Pernick, Helene F. Perry, Ralph W. Peterson, Warner Leland Peticolas, Harry E. Petschek, Wayne T. Picciano, Francisco Pico-Irizarry, E. Thomas Pierce, John Piper, Robert O. Pohl, Raymond Pollock, Jr., Yog Prakash, Francois Prevot, Fraser P. Price, Joseph U. Raffo, III, V. V. Raman, John L. Rawls, Puligandla Ramakrishna, Harrison E. Radford, Robert L. Ramey, John D. G. Rather, Gerald Joseph Rausa, A. Lincoln Read, Avraham S. Reiner, Fremont Reizman, Eli Reshotko, Clayton Ellington Reynolds, Riaz-Ud-Din, Joseph Francis Roach, Frederick E. Romberg, John Allen Rosado, Arthur J. Rosenberg, Joseph E. Rowe, John H. Rowen, Barrie S. H. Royce, A. R. Ruffa, Sigsby K. Rusk, Jr., Emile Rutner, Matthew G. Ryan, Patrick G. Sandars, Harvey Sanders, Carlo Schaerf, Emil Schafer, Werner Schneider, Henry Claude Schindler, David Shoenberg, Lawrence C. Scholz, James F. Schooley, George F. Schrader, Thomas Parker Seitz, Theodore Britton Selover, Jr., John Rector Sevier, John Wayne Schultz, Sheldon H. Schuster, Raymond Sedney, Jay M. Shapiro, Joseph J. Sheppard, Jr., Gordon Alexander Shiffrin, Ya'akov Shima, Herman Shuman, Harold J. Siegel, Köhler H. Sigurd, Oktay Sinanoglu, Jagan Nath Singh, Lawrence Sirovich, Bernard J. Skopp, Darryl B. Smith, Frederic P. Smith, Myron C. Smith, Benny Anthony Soldano, Ernst H. Sondheimer, Joseph Sperrazza, Maurice P. Spighel, William O. Statton, Ronald F. Stauder, Herman J. Stein, Robert P. Stein, Johanna E. Sterbin, Sheldon D. Strauss, Robert Street, H. Eugene Stubbs, Klaus G. P. Sulzmann, Bruno Svinis, Robert A. Swanson, Charles D. Swift, Stanley D. Tanenholtz, William R. Tarello, Gerald Reed Taylor, Jr., Wade J. Temple, John R. Thomas, Marlin O. Thurston, William H. Tobin, Jr., David Treves, Michel George Trocheris, Maurice Tucker, Roy Stephen Tucker, Casper J. Ultee, Homer B. Utley, Manuel Valadares, John I. Valerio, Peter Thomas Vandehei, Arie van Steenbergen, Lulio Vargas-Vinas, Yatendra Pal Varshni, Willem Vedder, Richard Hugh Vernon, Misri Lal Vatsia, Sandro Vitale, Ihor Myron Vitkovitsky, Bernard Vittoz, Hans Udo von Schultz, Frederick Vratny, Arthur A. Vuylsteke, Y. D. Wadhwa, Joseph A. Wagner, Mardell David Wagner, Hugo Donald Wahlquist, John R. Walker, John E. Warren, Tsutomu Watanabe, Robert Earle Weaver, William T. Weeks, Lawrence R. Weiss, Jean E. Welker, Herbert J. Werntz, Robert G. West, Russell G. Westberg, E. Whalley, Grace M. Wieder, Philip E. Wigen, Jerry H. Wilson, Dale T. Wingo, S. B. Woods, Arthur Eugene Woodward, Jiro Yamaguchi, Drasko D. Yovanovitch, John David Young, Robert A. Yount, Ricardo N. Zapata, Nadim H. Zebouni, Martin Zlotnick, and Robert Zolnerzak.

Elected to Student Membership on November 25, 1960: Albert E. Abey, J. Barclay Adams, J. Clifton Albergotti, Paul Walker Allison, Paul R. Auvil, Jr., Charles Baltay, John Paul Barach, Bette Lee Barton, Richard Donald Barton, Mariano V. Bauer, Philip B. Beilin, Virgilio Beltran-López, Walter Benenson, Martin Berman, Ivan Bernal, Van Bluemel, Olaf Alexander Boedtker, Richard D. Boyle, Marc H. Brodsky, Robert L. Brown, David Gunter Browning, Donald L. Bullock, Glenn A. Burdick, Philip B. Burt, Nicholas Bykovetz, Joseph Cerny, Ramesh Chand, Delano P. Chong, Tony L. Clark, Alan Hugh Colen, George T. Condo, Athanassios Costikas, David R. Curott, John B. Czirr, Arnold J. Dahm, Ned Tsunoo Dairiki, Richard L. Dangle, Gerald M. Daniels, Walter Edgar Daniels, Jr., Alfred J. Darnell, Walter J. Davis, Bobby C. Deaton, David A. Depatie, Leslie C. Dirks, David Louis Dittmer, Robert D. Dobrott, Norman Dombey, Stanley Ivan Drasky, Theodore R. Duncan, James R. Durig, DeLyle Eastwood, Daniel Edelman, Albert George Engelhardt, Peter Enis, Edward Erath, Edwin F. Erickson, Norman M. Evensen, Huoo-Long Fann, Thomas Ferbel, Lawrence August Ferrari, William J. Fickinger, Donald R. Finch, Henry E. Fisk, James Lee Foster, Jr., Clifford W. Fountain, Frank A. Franz, Norman Freed, Lyman Jefferson Fretwell, Jr., Robert Futrelle, N. K. Ganguly, Vitalij Garber, David A. Garelick, James W. Garland, Jr., Robert J. Berbracht, Joseph Gezelter, Joseph Natale Ginocchio, Michael Gold, Iza Goroff, Harold C. Graboske, Jr., Reinhard Graetzer, Carl L. Gruber, Harold Lewis Grubin, John Lewis Hall, In Gun Han, Robert John Hardy, Walter B. Hatfield, Hans J. Hennecke, Donald H. Hensler, Norman E. Holden, Robert W. Hougardy, Cecil I. Hudson, Jr., F. Russell Huson, Robert L. Intemann, William M. Irvine, William M. Jackson, Richard J. Jacob, Harry C. Jacobson, Philip B. James, Charles A. Johnson, M. Thomas Jones, Minao Kamegai, Ik-Ju Kang, Albert Daniel Kauffman, John Boyd Ketterson, Jhan Mohammed Khan, Yeong E. Kim, Thomas A. Kitchens, Jr., John W. Kohl, K. L. Kowalski, William R. Kropp, Jr., Alan V. Larson, Norman R. Lebovitz, Ronald Dorian Levine, Thomas R. Loree, Peter Love, Roy Love, E. P. Lovejoy, William S. Lovell, K. Brooks Low, Marshall Luban, Edward James Ludwig, Yan Naing Lwin, Richard Kenneth Lyon, Robert J. Macek, James A. MacLachlan, Jr., James M. Mangan, Gerald Mandel, A. Ransom Marlow, Alfred W. Maschke, Joseph F. Masso, Wesley N. Mathews, Jr., M. Stephen Maxon, Robert Earl McDonald, Joseph Peter McEvoy, Jr., James C. McGroddy, J. L. McNichols, John Melngailis, Frank Lee Miller, Robert L. Miller, DeLee F. Minner, Richard M. Mobley, Fred A. Morse, W. D. Moseley, Jr., David McLeod Moulton, Gardiner H. Myers, C. S. Naiman, James K. Neeland, L. Dean Newman, Lee Q. Niemela, Carl Marcus Noble, Jr., Robert J. Oakes, Binyork Ouyang, James W. Overbeck, Jae Young Park, Ronald Dee Parks, W. E. Parry, Robert M. Pearlstein, Robert Pecora, Keith S. Pennington, Dennis Allee Phillips, Allan Dale Pierce, William L. Pierce, Arturs H. Piksis, Michael E. Pittman, Russell M. Pitzer, Fred Hugo Pollak, James C. T. Pool, John R. Porter, Shanker Prasad Pradhan, Henry J. Prask, Franklin M. Propst, Carroll A. Quarles, Jr., Kenneth R. Rafanelli, Mahlon Raymund, Neville W. Reay, Jr., James J. Reidy, Gough C. Reinhardt, Charles A. Rey, Ralph D. Reymond, Earle Wesley Richardson, Jr., Rogers C. Ritter, Charles M. Robb, Francois M. Rostas, Allen Rothwarf, David L. Sachs, Mark Sakitt, Gerhard L. Salinger, Paul R. Satterblom, Richard A. Scholl, David M. Schrader, Joseph H. Schulman, Benny Segal, Jerrold A. Seitchik, Margaret Ann Shea, Arthur Robert Sherwood, Lieng Chen Siew, William Silvert, James Sinnis, Andrew M. Smith, Robert Stuart Snyder, Ojars J. Sovers, Harvey J. Stapleton, Nelson Stein, Aldred Lyman Stevens, David Stonehill, Richard P. Storm, Alan G. Strehoff, Raymond Edward Struzynski, Eric Stusnick, Ronald K. Sundfors, Daniel J. Tambasco, Setsuko Tanaka, John A. Taylor, George H. Thomson, Donald H. Tompkins, Cheng Seng Tsai, Frank M. Tsujihara, Kenneth C. Turner, Elizabeth R. Tuttle, Bruce W. Wachhozz, Richard L. Wagner, Jr., David Francis Wait, William A. Walker, Jr., David L. Weaver, Dale Webb, Lennard Wharton, Jason M. Wilkenfeld, Charles E. Williams, Robert Roland Wilson, Kai-Wai Wong, John H. Worner, Yacob Aziz Yacob, York-Peng E. Yao, David H. Yen, Thomas H. Zepf, and J. D. Zund.

Errata Pertaining to Abstracts C1, Q9, and SP3 of the 1960 Chicago Meeting

(Series II, Vol. 5, No. 6)

C1 by R. S. Claassen. In Eq. (1), instead of

$$\left(\frac{\epsilon-\epsilon_d-\zeta_V}{eV}\right)^{\frac{1}{2}}(V-V_F)$$

read

$$\left(\frac{\epsilon-\epsilon_d+\zeta_V}{eV_D}\right)^{\frac{1}{2}}(V_D-V_F).$$

Q9 by Joseph G. Barredo. In footnote 1, instead of "H. Margenau and . . .," read "Louis de Broglie, *Non-Linear Wave Mechanics: A Causal Interpretation* (Emig Company, 1960)."

SP3 by Joseph G. Barredo. In the title, instead of "Course Concept," read "Cause Concept." In footnote 1, instead of "Phil. Trans. Roy. Soc. (London)" read "Phil. Sci."

Minutes of the 1960 Winter Meeting in the West Held at the University of California, Berkeley, December 29–31, 1960

THE registration total of 760 physicists at the West Coast Winter Meeting of the American Physical Society was a total somewhat larger than expected because of the Strong Interactions Conference sponsored by our Society and held also at Berkeley; it began on December 27 and continued through the 29th. The minutes of the Conference on Strong Interactions will appear in a forthcoming issue of *Physics Today*. A full account of its proceedings will be found in the July issue of the *Reviews of Modern Physics*. The size of the meeting was still small enough to retain a flavor of relaxation and absence of frustration in having no more than four parallel sessions, and on some days there were only three parallel sessions. There was time for talk and discussions over continual coffee which was served by the Physics Department during all the days of the meeting. We should relish such small meetings because it is feared by many that the time will soon come when small West Coast meetings will be a thing of the past, just as small meetings disappeared for the East Coast long ago.

The subjects for the meeting were rather well balanced, with strong emphasis on nuclear physics and solid-state physics. Particularly interesting sessions on biophysics and astrophysics attracted a rather large audience of nonspecialists. The regular program of the Society consisted of 111 contributed papers, 8 post-deadline papers, and 24 invited papers.

The attendance at the banquet held at the Hotel Claremont on December 30 was 170 people. The presiding officer was Professor V. F. Weisskopf, and the after-dinner speech on "Teaching of Physics" was given by Professor E. Segrè. This was preceded by a few remarks by Professor R. T. Birge and a welcoming speech on behalf of the University of California given by Chancellor G. T. Seaborg.

The American Physical Society is particularly grateful for the complete sponsorship of two cocktail parties, one for the Strong Interactions Conference, the other for the American Physical Society meeting, by the following companies: Electro-Optical Systems Inc.; Fairchild Semiconductor Corporation; General Atomic; International Business Machines Corporation; Philco Western Development Laboratory; and Space Technology Laboratories, Inc.

The Local Chairman for the meeting was Professor H. A. Shugart, who did a magnificently efficient job. We all look forward to him as the next Deputy Secretary for the Pacific Coast in the next year.

E. L. HAHN

Errata Pertaining to Abstracts A4, C6, and H6 of the 1960 Berkeley Meeting, and to papers 4A and 4B of the Conference on Strong Interactions

(Series II, Vol. 5, No. 7)

A4 by J. I. Budnick, L. J. Bruner, E. L. Boyd, and R. J. Blume. From line 7 on, instead of "The addition of . . ." read "The NMR signal is rapidly attenuated with the addition of solute in both cases, with no appreciable shift in resonant frequency."

C6 by Mark J. Jakobson. In the fifth line from the bottom of the abstract, instead of "13.0±0.20 mb at 2.95 Mev," read "1.30±0.20 mb at 2.95 Mev."

H6 by W. Gilbert Clark. Instead of "intrinsic values of T_1 are fitted by . . . ," read "intrinsic values of $(1/T_1)$ are fitted by . . . ."

4A by A. M. Schwartz and **4B** by F. S. Crawford, Jr. (Conference on Strong Interactions). Titles of these two papers were identical with the title of the Session which was "Λ Cusp at Σ Threshold."

Minutes of the 1961 Annual Meeting

THE 1961 Annual Meeting was held at New York from Wednesday through Saturday, February 1–4, mainly in the Hotel New Yorker but with sessions also in two other hotels and in the Manhattan Center. Like its predecessors it was a record meeting, but not by much of a margin—3937 registrants against 3865 last year and 3609 the year before, 426 contributed papers against 419 last year and 359 the year before. This betokens a condition of near-stability, but this fact combined with our experience of other annually recurrent meetings awakens in us the sort of premonition that the neighbors of a volcano feel when their volcano has been dormant for quite a while. We have no way of distinguishing how the registrants should be accredited as between our Society and the American Association of Physics Teachers (with which, as usual, we shared the registration facilities, the Joint Ceremonial Session, and the banquet). Neither do we know to what factors to attribute the singular fact that in registration this meeting is always much bigger than the Spring Meeting in Washington while in number of contributed papers it is always smaller: charm of the Metropolis? presence of the AAPT? greater expectations from the Placement Service? The delights of winter travel can hardly be considered a factor, or if they have been they will perhaps now cease to operate as such, since on the last-but-one-day of the meeting the city was struck by a snowstorm so severe that not only were the Saturday sessions impaired by lack of suburban visitors, but some of the out-of-town members got an extra day or two in town for want of outbound planes. Speaking of the sessions, we were as usual afflicted by the fact that our biggest halls were much too small for our biggest sessions while our smaller ones were often more than ample for the smaller sessions. We hope but cannot promise to do better next year.

At the Joint Ceremonial Session, President Weisskopf gave his Retiring Presidential Address "Problems of Nuclear Structure." (During the AAPT part of this impressive convocation, Jerrold Zacharias received the Oersted Medal and W. A. Fowler gave the Richtmyer Lecture.)

At the Business Session of the Society, before the very few who attended it, S. A. Korff, the Chairman of the Board of Tellers, reported the outcome of the elections lately over: Frederick Seitz was to become and (at the end of the Annual Meeting) did become President of the Society, W. V. Houston its Vice-President, L. G. Elliott and Polykarp Kusch entered upon its Council, Karl K. Darrow, S. L. Quimby, and S. A. Goudsmit continue as Secretary, Treasure, and Managing Editor, respectively (the last-named holding over). To the Board of Editors were elected P. W. Anderson, Gregory Breit, Charles Kittel, C. C. Klick, T. D. Lee, K. Watson, W. P. Allis, and Ugo Fano—the first six of these are to be concerned with *The Physical Review* and the last two with the *Reviews of Modern Physics*. Further, the Chairman of the Board of Tellers announced the adoption of the Amendment to the Constitution published on page 390 of the 1960 Bulletin and circulated to the membership-at-large. Through this Amendment our Council was empowered and directed to add to its membership at each Annual Meeting a nonvoting Councillor to serve for two years; W. P. Slichter has become the first to hold such a post. Howard A. Shugart was appointed Deputy Secretary for the Pacific Coast to succeed E. L. Hahn at some time during the Summer of 1961.

The banquet of the two Societies was held at the Hotel New Yorker on Friday evening, with an attendance of 492, an all-time record for the Annual Meeting and possibly for the whole history of the Society; H. A. Bethe, who spoke under the title "Physics and Politics," may well feel gratified. At the banquet also the 1961 Oliver E. Buckley Solid-State Physics Prize was awarded to Walter Kohn, and the Secretary ought not to dissemble the fact that he was honored by a very pleasant testimonial to his twenty years of service, or rather by two, one of them spoken by J. H. Van Vleck and the other written (we are told) by W. W. Havens and perpetuated on a scroll.

Emily Wolf and other members of the Institute staff in great number are to be warmly commended for managing the tremendous congress so very well.

Elected to Fellowship on January 31, 1961: John T. Agnew, Joseph Ballam, Richard G. Barnes, Joseph L. Birman, Frank J. Blatt, Ivor Brodie, Laurie M. Brown, Max E. Caspari, Michael Cohen, W. Dale Compton, Jerome M. Dowling, George Feher, Sherman Frankel, Theodore H. Geballe, Alexander N. Gerritsen, Leonard S. Goodman, J. Mayo Greenberg, Evan O. Kane, Alfred Leitner, Archie Mahan, Harold Mendlowitz, Gerald S. Picus, John M. Richardson, Walter Selove, David P. Shoemaker, Stanley Cooper Snowdon, and Joseph Weber.

Elected to Membership on January 31, 1961: Juana Viro Acrivos, Edwin R. Ahlstrom, Donnie L. Ainsworth, George Gregory Alexopoulos, Georges Ambrosino, M. F. Anderson, Tetsuo Asami, John M. Bailey, Kanwal Singh Balain, James Banks, Louis J. Barbieri, Lynn M. Barker, R. Edward Barker, Jr., Ernesto Barreto, Dorothy Jane Bearcroft, Roland Charles Michel Beeh, Paul L. Belgodère, Robert S. Bergman, Brother Austin Bernabei, Maurice G. A. Bernard, Morton Mark Bernstein, Abraham Bers, Robert M. Blakney, Marshall Blann, Norbert N. Bojarski, Gary D. Boyd, James R. Boyd, Vincent M. Boyle, Dermot James Bredin, Thomas Peter Brody, Carl Anthony Brown, Norman Brown, Robert H. Bullis, Paul S. Bushnell, Jr., James H. Cannon, Barney

J. Carr, John W. Carson, Stanley L. Carts, Jr., Jean-Pierre Causse, Thomas James Cebulla, George A. Champine, Joseph H. Chen, George Cheroff, Arthur Bennett Cicero, Glen T. Clayton, R. M. Crandall, William Culshaw, Melvin A. Dachs, John T. Daley, Jr., Robert Sheiman Davidow, Malcolm Federick Davis, Pieter C. T. de Boer, Robert T. Deck, Hans J. Degenhart, Herman P. Deinken, Jean De Prins, Albert N. Diddens, John E. Dove, David E. Downie, William C. Dunkerly, Richard J. Ellis, Sverre Thorstein Eng, Thomas P. Evans, C. W. F. Everitt, José Antonio Fernández, David A. Forejt, Harold E. Foster, Zoltan-Fried, Gerald J. Franz, Fritz J. Friedlaender, Harold Paul Furth, Erwin Gabathuler, Charles C. Gallagher, Carl G. Gardner, Jr., Wilbur Garriel, Seymour Geller, Thomas E. Gibson, Jr., Gordon A. R. Graham, Daniel Gross, Chester Gross, Chester Lee Grubbs, Hendrik F. Hameka, Marvin L. Harding, Victor Harrap, Wynford Lewis Harries, Frank Lyman Hassler, John B. Hatcher, Hermann Anton Haus, Joachim Jacques Hauser, Richard Frank Heitmiller, Walter C. Henneberger, Anton N. J. Heyn, Otto H. Hill, Herbert Hollister, Jen Hsu, Richard A. Hubach, William M. Hubbard, Roland A. Hultsch, Robert P. Hurst, Sherman Jaffe, Richard C. Jarnagin, Walter Jekeli, Norman C. Jen, Thomas F. Jennings, Jr., Julian F. Johnson, Vernon J. Johnson, Jean P. Perez Y Jorba, Pandurang M. Kamath, Howard Katz, Irvin Kay, Ying Chao Kiang, James E. Kiefer, Jack B. Kinsinger, Wolfgang Knauer, Paul M. Koehm, Herbert Kurss, James C. Laurence, William M. Learens, Jr., Bernard W. Levinger, Riccardo Levisetti, Martin Lipeles, Wolfgang H. Lohmann, J. William Luebbe, Jr., Donald H. Lyon, Ronald Duncan Macfarlane, Gary E. Maciel, Walter M. Macintyre, Allen J. MacKinnon, Waldo G. Magnuson, Jr., Roe Johnson Maier, Jr., Farley Bary Malik, Charles R. McCoy, Ernest E. McCoy, Jr., Robert G. McMichael, Morton E. Milberg, H. Craig Miller, Richard B. Minch, Richard E. Mirabelli, Harold Mirels, William C. Moreland, Jr., Daniel Morellet, Morgan Jay Morley, M. Luis Muga, Nivarthi S. Satya Murthy, Challa Radhakrishna Murty, John A. Mydosh, Peter B. Myers, Ryosuke Namazu, Suen Gosta Nilsson, Tomota Nishi, Donald W. Nyberg, Zukio Obata, William E. O'Brien, Toshihiro Okada, Koichi Okamoto, Irene B. Ortenburger, Norman Ray Ortwein, Roger A. Otte, Alan E. Owen, C. H. T. Pan, John B. Pegram, John Philips, C. Raymond Pierce, Tseng Poh-Kun, Wing G. Pon, Sergio P. S. Porto, Robert C. Powell, Carle Amon Privette, Donald Lawrence Puppione, George W. Racette, Jr., Leonard F. Rago, Melukote K. Ramaswamy, Stuart A. Ramsden, John V. Recesso, Donald C. Reynolds, Joseph Elmer Rhodes, Jr., Martin L. Rosenzweig, Leslie A. Roslund, Marvin H. Rowe, Topendra C. Roy, Arthur L. Ruoff, Gary Rhue Russell, Tomoyuki Saito, Jerome S. Sallo, S. Sampanthar, John Santomieri, Walter Sawchyk, Robert I. Schermer, H. J. L. Schuurmans, L. E. Scriven, II, William A. Scyudga, Knut Norbert Seeber, Thomas E. Seidel, Walter Seitz, Dipak Lal Sengupta, Darwin W. Smith, Erich J. Stegelmann, James O. Stiegler, G. Harry Stine, Ernest H. Stockhoff, Robert W. Stooksberry, Toshimiko Suzuki, Louis A. Svach, Geza V. Szamosi, Michael E. Szekely, Shigeya Tanaka, Ichiro Taniguchi, Jason R. Taylor, George E. Thomas, Jr., Arthur C. Thorsen, Jr., Allen B. Timberlake, James R. Tomlinson, Louis Tonik, Mario P. Tosi, Philip T. Tracy, William L. Trousdale, Tillman Jesse Tucker, Jr., Almon G. Turner, George James Unterkofler, John M. Vail, Gordon Vandervort, Bruce D. Van Deusen, Andrew C. Vastano, Allyn R. Von Neida, Bayram Vural, James A. Waggoner, Walter D. Wales, Philip Leroy Walker, Jr., Frederick E. Wang, Ernest Wantuch, John William Wassel, C. Marvin Wayman, Robert Allen Weagant, Thomas A. Weber, Hans A. Weidenmuller, Melvin M. Weiner, T. J. Weismann, Joseph F. Weller, Leland M. Welsh, Claude Finley Williamson, G. Richard Wirtenson, Harlow Wright, Mohammed Yaqub, H. Y. Yeh, Tsu-Hsing A. Yeh, Teh Fu Yen, and Akio Yoshimori.

Elected to Student Membership on January 31, 1961: Maris A. Abolins, Farid Fadlow Abraham, S. P. Agarwal, Jack Aldridge, III, Philip L. Altick, Sidney Altman, Donald L. Ameen, N. Curtis Anderholm, J. Gerard Anderson, Gordon E. Bairo, Richard H. Ball, Barry C. Barish, Virgil E. Barnes, II, Robert C. Bearse, David G. Becker, J. E. Belyea, Anand Kumar Bhatia, William D. Botch, Kayland Zane Bradford, Donald D. Briglia, Judith Claire Brown, William J. Burke, Donald Wayne Busse, William M. Bustin, David C. Camp, Howard T. Coffey, James B. Comly, James L. Cook, Roger Corneliussen, Donald Coyne, Victor Pereira Crespo, John F. Dawson, Melvin D. Daybell, Arthur Blanchard Denison, Mauro Di Domenico, Jr., Frank S. Dietrich, Jack S. Donaldson, Gerald Dorman, Patrick J. Dowling, Alex J. Dragt, Bob I. Eisenstein, Paul D. Feldman, Roger W. Finlay, Douglas B. Fitchen, Daniel F. Frerejacque, Ronald C. Frisch, Aaron D. Gara, Harry Gelman, William R. Gibbs, Forrest I. Glick, William A. Goddard, Albert Goldstein, Alan C. Greene, Samuel Norton Greenschlag, Hayes O. Griffith, Charles C. Grimes, Peter Grosewald, James F. Hadwin, James F. Hanlan, Robert B. Hemphill, Joseph W. Hemsky, Douglas J. Henderson, Tareah J. Hendricks, Charles H. Henry, George H. Hetley, Jr., Norman E. Heyerdahl, Harold Wheeler Hilsinger, Richard L. Hilt, Lester L. Hirst, Jr., Arthur K. Hochberg, Bernard Hoop, Jr., Henry O. Hooper, J. Richard Houck, George C. Ihle, Harumasa Ito, James F. Janak, Curtis D. Johnson, David Lee Johnson, James A. Jordan, Jr., Abraham Kadish, Raphael Kaplan, Hyun Chang Kim, James Karl Kliwer, Charles D. Knutson, Robert J. Kolouch, Alvin L. Kwiram, Richard C. Lamb, Peter Wolfgang Langhoff, David C. Langreth, Gerald J. Lapeyre, David W. G. S. Leith, Peter M. Levy, Bruce T. Lucas, Kotusingh B. Lulla, Yenmow Lynn, Eugene Maier, Arthur W. Martin, III, Fred Martin, Fred W. Martin, Joseph A. McClure, Jr., Alden McLellan, IV, Richard O. Mead, Manuel G. Menendez, Robert G. Mortimer, Fredrik A. Muller, Julius J. Muray, Jeremy I. Musher, Charles H. Neuman, James A. Norris, John H. Ormrod, Costas Papaliolios, Jerry L. Peacher, Gerald A. Pearson, Claude Michel Penchina, James M. Peterson, Robert L. Poeschel, David L. Portigal, Om Parkash Puri, Louis J. Raubenheimer, Jean Douglas Reed, Donald V. Reames, Teresa S. Ree, E. Paul Riedel, A. André Rollefson, Kenneth L. Rose, Jules Lazar Routbort, Myron B. Salamon, Edward B. Saloman, Douglas Scalapino, Lee H. Schick, Claude Henry Schultz, Shuang-Yuan Shieh, Leonard M. Simmons, Jr., Winthrop W. Smith, Rex J. Snodgrass, Fred W. Spong, Robert J. Spry, Howard M. Stainer, Norbert Stankiewicz, Murray Steinberg, Donald Stern, David Stoler, Norman Strax, Moj-taba Taherzadeh, Ivo Tammaru, Jacques D. Templin, Stevens P. Tucker, Allan F. Turpin, Jr., Lonnie Lee Ván Zandt, William L. Walters, H. Lee Watson, Burnell G. West, Grover C. Wetsel, Jr., Walter V. Weyhmann, Robert B. White, Charles L. Wiley, Fred A. Wolf, Samuel S. M. Wong, Robert W. Woolfolk, Joseph Stephen Wrobel, and Hector Zayas-Aguiar.

Errata Pertaining to Abstracts I6, J3, Q9, and Y7 of the 1961 New York Meeting

(Series II, Vol. 6, No. 1)

I6 by N. R. Fletcher, D. K. Tilley, and R. M. Williamson. Instead of

"$0.05 \leq \Gamma_\gamma(E2)/\Gamma_\gamma(M1) \leq 0.3$"

read

"$0.05 \leq \Gamma_\gamma(E2)/\Gamma_\gamma(M1) \leq 1.0$."

J3 by M. Ferentz and W. B. Teutsch. Instead of the reference "† Abstract separated from those on plasma physics at authors' request." read † "Request of authors misinterpreted as desiring that this paper be given elsewhere than in plasma physics session."

Q9 by P. N. Trehan, R. Rikmenspoel, and D. V. Van Patter. In line 11, instead of "γ rays, with a branching ratio (crossover/cascade) $= 1.7 \pm 0.1$" read "γ rays with a branching ratio (crossover/cascade) $= 0.9 \pm 0.1$." In line 15, instead of "0.8 ± 0.3." read "0.6 ± 0.2."

Y7 by J. C. Walker and D. L. Harris. Replace the sentence beginning with the words "From the quadratic shifts" by the following: "From the quadratic shifts observed in the resonances corresponding to these transitions we obtain the following very approximate results: $|a| = 35 \pm 20$ Mc/sec $|b| = 11\,800 \pm 1600$ Mc/sec with $b/a > 0$." Also, replace the sentence beginning with the words "It should be noted" by the following sentence: "It should be noted that the above value of $|b|$ leads to a value of $|Q| > 5$ barns and results in a rather unusual zero-field hyperfine level ordering."

Minutes of the 1961 "March" Meeting in Monterey Held at the U. S. Naval Postgraduate School, Monterey, California, March 20–23, 1961

WITH some apprehension following the surprising news that 412 abstracts, 9 post-deadline papers, and 46 invited papers were to be delivered at the Monterey meeting, the U. S. Naval Postgraduate School braced itself for the material requirements and convenience of an estimated attendance of 1200. The meeting went along smoothly and the weather, as though it was ordered, was clear and sunny for four days. The worst casualty befell the Division of High Polymer Physics, which expected to have in attendance about 100 people, but instead had about double that number; the lecture hall assigned to their sessions proved too small. There were 1155 people who registered. Six parallel sessions per day with a particularly concentrated conflict of interests on the first day were necessary. Such a compression in the first few days, with topics of quite a different nature assigned to the fourth day, was necessary in order to avoid conflict with the Quantum Electronics Conference (not sponsored by our Society!) which began in Berkeley on the fourth day of the American Physical Society meeting. [The scheduling of the Conference to overlap with our meeting was deplored by many, and efforts will be made to prevent another such occurrence.—K.K.D.] A stream of new developments in the fields of the Divisions of Solid-State Physics, Chemical Physics, and High-Physics poured from various laboratories in the East and filled a major amount of the agenda of the Bulletin. Invited and contributed sessions on nuclear physics also were included. The large attendance was never quite evident since most people were usually dispersed about the large expanse of the Navy School grounds. It appeared only during the Buckley lecture by Walter Kohn in the large auditorium of King Hall which was filled to capacity, thus calibrating the attendance to the stated number above.

The banquet of the Society had an unusually good attendance of 350 people and was preceded by a cocktail party. Following the welcoming remarks of Admiral M. E. Dorin, Professor Frederick Seitz, the new president of the Society, introduced Dr. Donald K. Stevens, Chief of the Metallurgy and Materials Branch, Division of Research, U. S. Atomic Energy Commission, and Mr. Charles F. Yost, of the Advanced Research Projects Agency. These people described briefly the mission of their government agencies in support of physical research. The final speaker of the evening, Dr. Robert Herman, of the General Motors Laboratories, gave a descriptive talk on "Traffic—Old and New," which was well documented with slides. The refreshing levity of Dr. Herman's rendition did well to relax all those present, fusing agreeably with the good California wine.

Not enough recognition can be accorded to the Local Committee at the U. S. Naval Postgraduate school, consisting of Professors J. R. Neighbours, *Chairman*, J. N. Cooper, and L. O. Olsen, for their response to the unusual demands made upon them to accommodate what, in effect, was a national meeting. Thanks also are due Dr. F. R. Buskirk for his faithful assistance to details and Mr. Peter Liepman for his masteful arrangements of the cock-

tail party and banquet. By good fortune, the city of Monterey is blessed with a progressive and efficient Convention Bureau, and its attention to details of bus service, pamphlets, and secretarial service is gratefully acknowledged. We thank particularly Mrs. Carolyn Brewer, of the Monterey Peninsula Convention Bureau, who took charge of these matters.

E. L. HAHN

Errata Pertaining to Abstracts NA6 and Y2 of the 1961 Monterey Meeting

(Series II, Vol. 6, No. 2)

NA6 by Solomon Zwerdling and John P. Theriault. (1) In the second sentence, instead of ". . . and 15 clearly defined . . ." read ". . . and 16 clearly defined . . .," (2) Replace the third sentence beginning with the words "Upward curvature . . ." with the sentence "Upward curvature with increasing field was evident in the shift of the lower component of the spin-split transition involving the lowest conduction band magnetic level, as expected for transition to exciton levels." (3) In the fourth sentence, instead of ". . . yields a g factor of 43.5 ± 0.5, somewhat . . ." read ". . . yields a g factor of 48.0 ± 0.5, somewhat. . . ." (4) In the seventh sentence, instead of ". . . gap found was 0.237 ± 0.002 ev as determined . . ." read ". . . gap found was 0.2357 ± 0.0005 ev as determined. . . ."

Y2 by Robert G. Morris and Jerome G. Hust. In line 17, instead of 0.011 ± 0.02," read 0.11 ± 0.02."

An Apology

Deplorable delays have occurred and are occurring in the servicing of orders for journals and in the recording of changes of address for our members. These result from the changeover to a new business-machine system in the office of the American Institute of Physics, which handles all such matters for us. The Institute is making every effort to overcome the difficulties, and it joins its apologies to ours.

Pertaining to the 1962 Dannie Heineman Prize

A Dannie Heineman Prize will become available for award in 1962. The stipulation for the prize is that it be awarded "for outstanding articles in the field of mathematical physics published in scientific journals." There is no stipulation as to nationality, place of residence, or age of prizewinners, nor as to the locality in which the work was done. Anyone who wishes to suggest a candidate for this prize may write to Chancellor W. V. Houston, William Marsh Rice University, Houston, Texas.

Communication from the Treasurer

For the information of the members the Treasurer presents the following statements condensed from the report for the year 1960 of Conroy, Smith and Company, auditors, as presented to the Council at Washington on April 24, 1961.

SHIRLEY L. QUIMBY, *Treasurer*

OPERATING INCOME AND EXPENSES ALLOCABLE TO THE YEAR ENDING DECEMBER 31, 1960

Income:				
Membership dues			$245 360.50	
The Physical Review				
Income:				
Nonmember subscriptions	$148 058.19			
Published articles	211 723.40			
Sale of back numbers	9 264.86			
Membership subscriptions	74 629.31	$443 675.76		
Expenses:				
Cost of production and distribution: 7876 pages to 7691 member and 3602 nonmember subscribers	$392 763.42			
Editorial office	49 832.99	$442 596.41	$ 1 079.35	
Reviews of Modern Physics				
Income:				
Member and nonmember subscriptions	$ 55 603.85			
Published articles	12 018.67			
Sale of back numbers	5 926.56	$ 73 549.08		
Expenses:				
Cost of production and distribution: 1056 pages to 1755 member and 9823 nonmember subscribers	69 322.29			
Editorial office	3 236.84	$ 72 559.13	$ 989.95	
Net receipts from dinners and registration fees			$ 3 233.75	
Dividends			3 044.50	
Interest on bonds			10 885.22	
Sale of *The Physical Review Cumulative Index*			134.73	
Prize award—Hughes Aircraft Company (Contra)			2 500.00	
Buckley Physics Prize Award Trust			250.00	
Miscellaneous			368.33	$267 846.33
Expenses:				
Office of Secretary and Treasurer:				
Salaries		$ 17 651.81		
Payroll taxes, insurance, and retirement fund		1 206.26		
Travel expenses of officers of Society		3 263.24		
General Office expenses		5 869.89	$ 27 991.20	
American Institute of Physics—collection of dues and subscriptions			21 430.68	
Physical Review Letters				
Income:				
Membership subscriptions	$ 30 347.65			
Nonmember subscriptions	25 121.06			
Published articles	39 332.19			
Sale of back numbers	2 253.41	$ 97 054.31		
Expenses:				
Cost of production and distribution to 5915 member and 2318 nonmember subscribers	$ 83 079.45			
Editorial office	36 770.78	$119 850.23	$ 22 795.92	

Bulletin—Cost of printing and mailing	$ 35 219.00		
Editorial mechanics—A.I.P.	4 821.36	$ 40 040.36	
Deduct income from subscriptions		6 470.61	$ 33 569.75
Cost of membership and reduced rate subscriptions in excess of amounts collected therefore:			
The Review of Scientific Instruments		$ 2 136.00	
The Journal of Chemical Physics		5 939.50	
Journal of Applied Physics		11 255.50	
The Physics of Fluids		1 840.00	$ 21 171.00
Contribution to Institution of Electrical Engineers			45 117.00
Contribution to American Institute of Physics for maintenance and support			22 126.60
Prize award (Contra)			2 500.00
Custodian fee			402.95
Ballots and postage expense charged by the American Institute of Physics			2 540.45
Miscellaneous			460.92 $200 106.47
Net income from operations of 1960			$ 67 739.86

Balance Sheet as of December 31, 1960

Assets

Cash on deposit:			
Checking account		$ 50 290.51	
Custodian account		11 429.50	$ 61 720.01
Accounts receivable: (Note 1)			
American Institute of Physics			79 010.27
Investments—at cost:			
Bonds (market value $312 574.60)		$308 611.45	
Stocks (market value $145 038.00)		98 807.71	407 419.16
Deferred charges:			
Cost of membership and reduced rate subscriptions to various journals in excess of amounts collected therefore		$ 9 541.00	
Sundry		2.42	9 543.42
			$557 692.86

Liabilities and Accumulated Income

Accounts payable			
The Institution of Electrical Engineers		$ 13 459.70	
Division of Chemical Physics		734.46	
Others—for payroll taxes and expenses		16 088.73	$ 30 282.89
Deferred credits: (Note 1)			
Membership dues paid in advance		$108 994.88	
Subscriptions received from members applicable to issues of journals to be published subsequent to December 31, 1960:			
The Physical Review	$ 32 120.00		
Physical Review Letters	13 269.00		
Physics Abstracts and Engineering Abstracts	4 927.42		
Bulletin	945.40	$ 51 261.82	$160 256.70
Accumulated income at January 1, 1960		$299 413.41	
Add: Excess of income over expenses year ended December 31, 1960		67 739.86	367 143.27
			$557 692.86

Note 1: Does not include certain amounts received by the American Institute of Physics subsequent to November 1, 1960, and undistributed at December 31, 1960. It is our understanding that the greater part of these receipts are applicable to 1961 dues and subscriptions.

Announcement of a Cosmic-Ray Symposium in Mexico City

The organization "Consejo Latino-Americano de Radiación Cosmica," operating under UNESCO authority and conveniently known by its acronym "CLARC," is planning a Cosmic-Ray Symposium to be held in Mexico City very soon after our meeting. This will comprise original reports on current cosmic-ray work and review lectures for the benefit of students and other interested persons. The official languages will be English and Spanish. Tentative dates are June 27 through July 7.

Anyone who is interested will be welcome to attend this Symposium. The detailed programme, when ready, will be sent on request from the office of the Secretary of CLARC, who is Dr. Juan Roederer, Comisión Nacional de Energía Atomica, Avenida Libertador Gral San Martin 8250, Buenos Aires, Argentina.

Announcement of the 1961 Thanksgiving Meeting at Chicago

The 1961 Thanksgiving Meeting will be held at Chicago, in the buildings of the University of Chicago, on Friday and Saturday, November 24 and 25. The official hotel will be the Windermere, at 1642 East 56 Street, Chicago 37, Illinois. Deadline for receipt of abstracts will be September 22.

Announcement of the 1961 Winter Meeting on the West Coast

The 1961 Winter Meeting on the West Coast will be held in the buildings of the University of California at Los Angeles on Wednesday, Thursday, and Friday, December 27 through 29, 1961. Abstracts are to be sent to Professor Howard A. Shugart, Deputy Secretary for the Pacific Coast, University of California, Berkeley 4, California. Deadline for receipt of abstracts is Friday, October 20.

1961 International Conference on Photoconductivity

(*Not Proofread*)

The "1961 International Conference on Photoconductivity" will be held at Cornell University, Ithaca, New York, on August 21–24. Readers are referred to page 323 of the previous (Washington) issue of this Bulletin for a description of its scope and other details. Deadline is past. Those wishing to attend must so notify Dr. A. R. Hutson, Bell Telephone Laboratories, Murray Hill, New Jersey, not later than July 1.

International Conference on Chemical Physics of Nonmetallic Crystals

An international conference on Chemical Physics of Nonmetallic Crystals will be held at Northwestern University, Evanston, Illinois, from August 28 through August 31, 1961. Its "principal objectives are to survey the knowledge of binding in nonmetallic crystals, to review the understanding of point imperfections and impurities in these crystals, to clarify the chemical and physical aspects of binding and of defects, ... Subjects of major interest will include quantum theory of nonmetallic crystals, characterization of point defects in crystals, equilibrium properties of dilute solid solutions, and transport processes and point defects." This has been accepted as a Topical Conference of The American Physical Society (but its abstracts will not be published in our Bulletin). It is open to anyone desiring to attend, but no one will be admitted unless before July 1 he makes an "attendance request" to the Conference Secretary, who is Mr. O. C. Simpson, Argonne National Laboratory, Argonne, Illinois. Deadline for submission of abstracts is already past.

1961 Gaseous Electronics Conference

The 1961 Gaseous Electronics Conference, fourteenth of the series, will be held at the General Electric Research Laboratories ("The Knolls") at Schenectady, New York, on October 11–13. Former conferences were sponsored by our Division of Electron Physics, which still contributes a member to the Organizing Committee. This Conference has been accepted as a Topical Conference of The American Physical Society. Like its predecessors it is to deal with the basic collision processes occurring in ionized gases, with the mechanisms of electrical breakdown and those of operation of electrical discharges, and with plasma physics in general, but papers on specific devices are excluded. All members of the Society have the right to attend this Conference and to submit contributed papers, but the Organizing Committee may accept or reject these as it chooses.

Abstracts of contributed papers are to be sent to C. J. Gallagher, General Electric Research Laboratories, Schenectady, New York, and must reach him not later than August 25, 1961. Abstracts must conform to the same regulations as are imposed on those submitted for general meetings of the Society. The Organizing Committee will not accept a greater number of contributed papers than is compatible with its intent to keep the meeting within three days, to avoid simultaneous sessions, and to provide adequate time for presentation and discussion of the papers that are accepted.

1961 Autumn Meeting of the Division of Plasma Physics

Our Division of Plasma Physics will hold its 1961 Autumn Meeting at Colorado Springs, Colorado, from Wednesday through Saturday, November 15 through November 18. Abstracts of contributed papers, prepared according to the rules and instructions set forth in this issue of our Bulletin, are to be sent to Dr. Fred L. Ribe, Los Alamos, New Mexico. They must reach him not later than Friday, September 15.

1961 Annual Meeting of the Division of Fluid Dynamics

Our Division of Fluid Dynamics will convene at Berkeley, California, in the Hotel Claremont near the campus of the University of California, on the three days preceding Thanksgiving: November 20, 21, 22. This meeting will be devoted to various aspects of the physics of fluids, including hydrodynamics and surface waves, magneto-fluid dynamics, rarefied dynamics, shock-tube and shock-tunnel flows, turbulence and boundary layer phenomena, superfluidity, medical hydrodynamics, and astral fluid dynamics. The object of the Division of Fluid Dynamics is the advancement and diffusion of knowledge of the physics of fluids with special emphasis on the dynamical aspects of liquid, plastic, and gaseous states under all conditions of density and temperature. Abstracts of contributed papers of not over 200 words, prepared in accordance with the rules printed in this Bulletin, should be sent in duplicate to the Chairman of the Programme Committee, Wayland C. Griffith, Lockheed Missiles and Space Division, Palo Alto, California. Deadline date for receipt of abstracts is October 9, 1961. Hotel reservations should be made by writing directly to Hotel Claremont, Berkeley, California, mentioning that you will be attending this meeting of the Division of the Society.

MEETINGS AND DEADLINES THROUGH APRIL 1962

Place	*Meeting dates*	*Deadline date*
Mexico City	June 22–24	past
Chicago	November 24–25	September 22
Los Angeles*	December 27–29	October 20
New York	January 24–27, 1962	November 10
Austin	February 23–24	to be chosen
Baltimore	March 26–29	to be chosen
Washington	April 23–26	to be chosen

Abstracts for the meeting marked with an asterisk are to be sent to Professor H. A. Shugart, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date. Abstracts for the other meetings listed above are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. Take note that abstracts mailed the day before deadline day often fail to arrive in time: the last postal delivery of the day usually comes to our office before 2 p.m. For meetings handled at this office, *allow at least two days for abstracts sent by airmail from points east of the Mississippi, and longer for those sent from farther west.* Abstracts postmarked (at the point of dispatch) on deadline day are instantly rejected. No abstract postmarked (at the point of dispatch) on deadline day ever reaches the office on time, nor does any abstract postmarked at any point west of the Rockies on the day before deadline day. Some abstracts arrive with covering letters dated three or more days before the postmark; it may be a good idea for you to put your abstract into a United States mail box with your own hands. Finally, if time is scant, fold your abstract and mail it in an envelope of size $9\frac{1}{2}$ by $4\frac{1}{4}$ inches or thereabouts; for if you mail it in a "manila" envelope large enough to accommodate it without folding, it may very well arrive after the deadline. *The privilege of contributing papers to meetings of The American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

DIVISIONAL MEETINGS AND TOPICAL CONFERENCES (see pages 403 and 404)

Ithaca	Photoconductivity	August 21–24	Past
Evanston	Nonmetallic Crystals	August 28–31	Past
Schenectady	Gaseous Electronics	October 11–13	August 25
Colorado Springs	Plasma Physics	November 15–18	September 15
Berkeley	Fluid Dynamics	November 20–22	October 9

RULES AND INSTRUCTIONS FOR THE PREPARATION OF ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words or to its actual length in words, whichever is the greater; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words. By-lines are not counted as part of the 200 words, and therefore addresses are condensed to the minimum in them. If you want to spend a lot of your precious 200 words in describing your exact location and the exact compartment of your organization in which you work, you have that privilege.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten; *one must be an original*, the other may be an original or a carbon copy. *Carbon copies will not be accepted in lieu of originals:* they smear. *Abstracts* (including titles, by-lines, and footnotes) *must be double-spaced:* single-spaced manuscripts are too crowded to permit the editorial markings to be made with ease and clearness. *Each abstract must be confined to a single page:* if it is too long for a single page it is too long to be printed. If we receive an abstract typed on two pages, we print only its first page. *Write each abstract as a single paragraph:* the suppression of paragraphs costs time and labor to the editors. *Do not use very thin paper:* a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. *Tables too broad to fit into one column of the Bulletin will be left out.* The American Institute of Physics will bless you if you type first the title of your abstract in lower-case with capitalized initials, then your name in capitals, then the name of your institution in lower-case underlined with capitalized initials. It is a pleasure to report that those who qualify for this blessing are increasing in number but are still quite a bit short of 100% of the total. Issues of the *Bulletin* are always appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go into the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line.

It has now become an expensive business to make any change in an abstract, even the smallest, after it has been received. By order of our Council "A change in an abstract will be permitted only at the discretion of the Secretary or his deputy, and only if TEN DOLLARS is enclosed with the letter in which the change is requested." As heretofore, an abstract will not be withdrawn from proof unless the asker sends ten dollars with his request.

New Instructions

(*a*) *If it is wished that two abstracts be scheduled consecutively, write on the first "To be scheduled before abstract ..... by ....." and on the second "To be scheduled after abstract ..... by ....."*

(*b*) *In general, all instructions about an abstract should be typed at the bottom of the page that has the abstract on it, never in a covering letter. Covering letters get separated from abstracts!*

(*c*) *If a member insists that his paper be scheduled for a particular day or not on a particular day, he will get his wish, but usually at the price of having his contribution included in a session to which it is irrelevant.*

The American Physical Society

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Groups especially concerned with June, 1961 Meeting:

(a) For Publication of the Programme in Spanish: Marcos Moshinsky, *Coordinator*, F. E. Prieto, Marcos Mazari.
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